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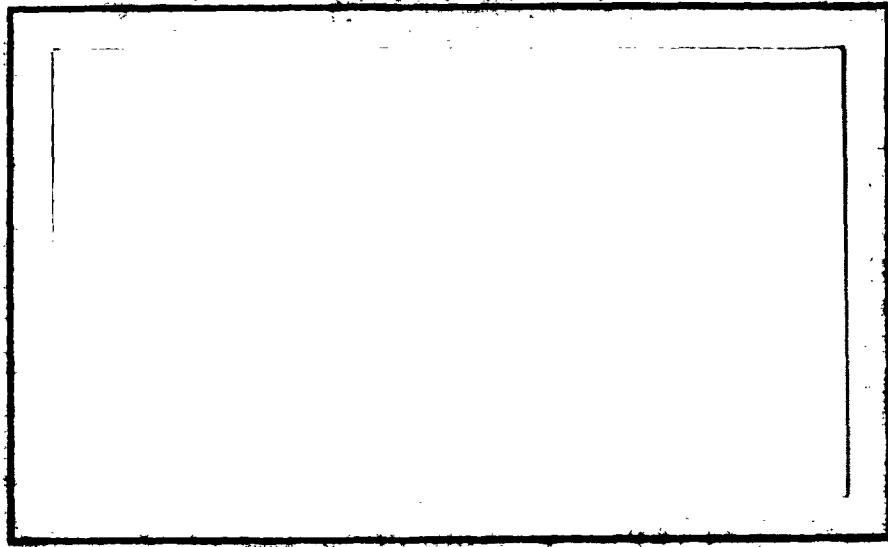
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BELL AEROSYSTEMS COMPANY
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BLR 62-26 (M)
10 December 1962

**TENSILE AND CREEP PROPERTIES OF
COLUMBIUM, TANTALUM, AND TITANIUM
ALLOYS AT ELEVATED TEMPERATURES**

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Division of Bell Aerospace Corporation**



BELL AEROSYSTEMS COMPANY

Engineering Laboratories

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TANTALUM, AND TITANIUM ALLOYS
AT ELEVATED TEMPERATURES**

**Bell Laboratory Report
BLR 62-26 (M)
December 1962**

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ABSTRACT

Tensile and creep tests were conducted on columbium alloys B-33, Cb-752, SCb-291; tantalum alloy Ta-10W; and titanium alloy Ti-13Cr-11V-3Al at elevated temperatures. The columbium alloys and Ta-10W were tested at 2800, 3100, and 3400°F. The titanium alloy was tested at 1800, 2050, and 2300°F.



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I. INTRODUCTION

Tensile and creep properties of various columbium alloys, a tantalum alloy (Ta-10W), and a beta titanium alloy were determined at elevated temperatures at the request of the Rocket Engineering Department for use in rocket motor designs. The alloys and test temperatures are listed below:

<u>Alloy</u>	<u>Nominal Composition</u>	<u>Test Temperatures*—°F</u>	<u>Supplier</u>
B-33	Cb-5V	2800, 3100, 3400	Westinghouse
Cb-752	Cb-10W-5Zr	2800, 3100, 3400	Haynes Stellite
SCb-291	Cb-10Ta-10W	2800, 3100, 3400	Stauffer Metals
Ta-10W	Ta-10W	2800, 3100, 3400	NRC
Beta Ti	Ti-13Cr-11V-3Al	1800, 2050, 2300	Unknown

- *1. The tensile tests on B-33 were run at 2750°F instead of 2800°F.
- 2. The tensile tests on Cb-752 were run only at 3100 and 3400°F.
- 3. The number of Ta-10W samples limited the tensile tests to 3100°F.

The Cb-1Zr alloy was originally included in the test program but was dropped when it became obvious that the strength levels of this alloy were well below the others at the temperatures involved.



II. TEST EQUIPMENT AND PROCEDURES

The specimens were tested in a Bell designed fixture in which the samples are heated by self-resistance and the loads are applied through hydraulic load cells. The current is regulated by a Westinghouse ignition control unit. The temperatures were measured by use of Pt-Pt 10% Rh thermocouples up to 3100°F and a Shaw two-color pyrometer at 3400°F. The samples were tested in an argon atmosphere obtained from liquid argon containers.

The load rate in the tensile tests was controlled to produce a strain of 0.003 to 0.007 in./in./min, as all of the alloys tested are strain rate sensitive. An X-Y recorder was used to automatically record stress versus strain.

III. TEST RESULTS

The results of the tensile and creep tests are shown in Table I and Figures 1-46. The number of Ta-10W specimens was limited; therefore, the majority were used in the creep tests as no creep data at these times and temperatures are available while tensile data is. The 3100°F tensile strength of the Ta-10W is comparable to existing data. The Cb-752 tests were limited to 3100 and 3400°F because of the number of test specimens.

The tensile data, Table I, shows that Ta-10W has the highest strength, but not the highest strength-to-weight ratio because of its high density. The Cb-752 had slightly higher strength than the SCb-291, which may be attributed to a higher degree of cold work; it was 0.020 inch thick as compared to 0.060 inch for the other alloys.

The titanium alloy is intended for use at temperatures other than these for the refractory alloys, and, therefore, no comparison is made.

Representative stress-strain curves for all alloys are shown in Figures 1-12.

The creep data (0.2 percent creep) are shown in Figures 13-46. The Ta-10W alloy had the highest creep strength, followed by SCb-291, Cb-752, and B-33 in that order. On a strength-weight basis, the SCb-291 had the highest rating.



TABLE I
TENSILE TEST DATA

Alloy	Nominal Thickness	Test Temp. °F	Y.S. (0.2% Offset) Psi	U.T.S. Psi	Elong. in 2" %
SCb-291 (Cb-10Ta-10W)	0.060"	2800	8,300	11,990	21.5 ⁽¹⁾
		3100	6,340	9,030	24.0 ⁽¹⁾
			6,070	8,700	23.5 ⁽¹⁾
		3400	4,720	6,570	25.0 ⁽¹⁾
			4,870	6,480	25.5 ⁽¹⁾
B-33 (Cb-5V)	0.060"	2750	8,300	11,050	34 (1)
			8,220	11,450	27 (1)
		3100	4,180	5,890	32 (1)
			4,030	5,590	31 (1)
		3400	2,205	3,370	28 (1)
			2,400	3,290	24 (1)
Cb-752 (Cb-10W-5Zr)	0.020"	3100	8,270	10,850	48.4 ⁽¹⁾
		3400	5,410	7,050	28.2 ⁽¹⁾
(1) This elongation value is low because of the arcing which occurs at the fracture.					
Ta-10W	0.060"	3100	10,850	15,850	22
Beta Titanium		1800	3,350	5,230	56*
			3,430	5,280	59*
		Av. 3,390		5,255	57.5
	2050	2,012	3,060	69*	
		1,790	2,530	66*	
	Av. 1,901		2,795		67

* Elongation values are probably low due to the arcing occurring at the fracture.

TABLE I (Continued)

<u>Alloy</u>	<u>Nominal Thickness</u>	<u>Test Temp. °F</u>	<u>Y.S. (0.2% Offset) Psi</u>	<u>U.T.S. Psi</u>	<u>Elong. in 2" %</u>
Beta Titanium	0.60"	2300	1,192	1,855	57*
			986	1,605	50*
			1,080	1,445	36*
		Av.	1,086	1,635	48

* Elongation values are probably low due to the arcing occurring at the fracture.

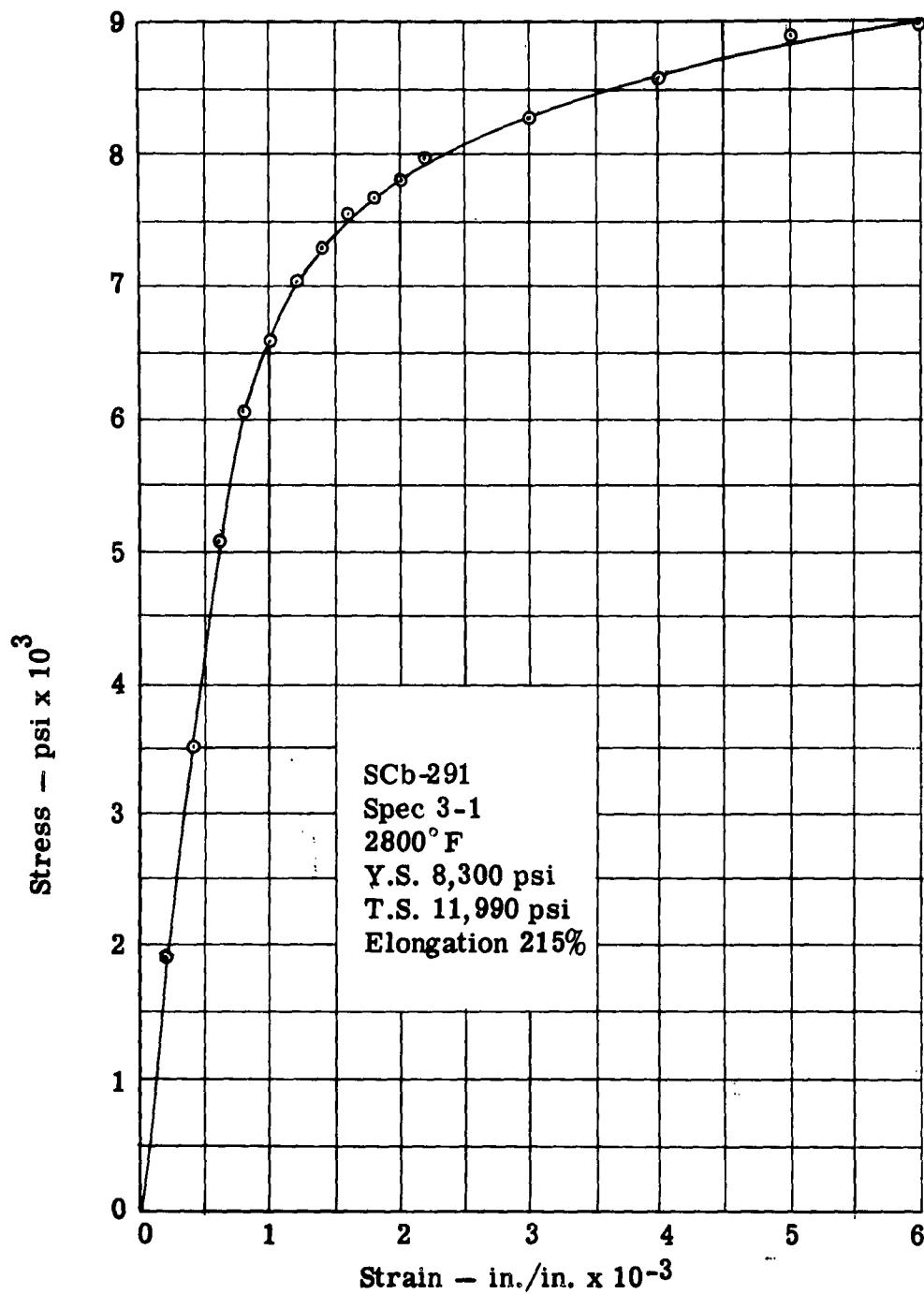


Figure 1. Stress-Strain Curve for SCb-291 Alloy at 3100°F



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SCb-291
Spec. 3-9
3100°F
Y.S. 6070 psi
T.S. 8,700 psi
Elongation 235%

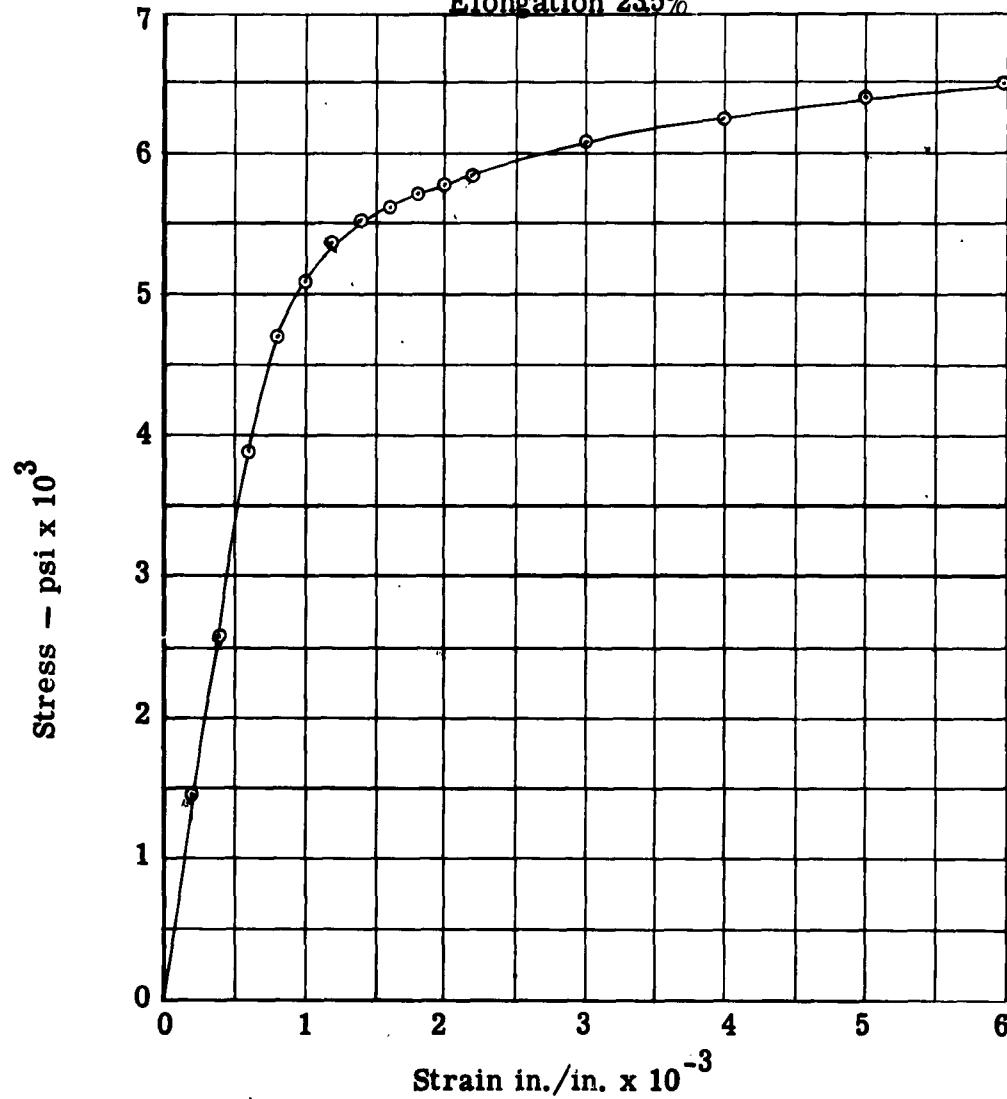


Figure 2. Stress-Strain Curve for SCb-291 Alloy 3400°F



BELL AEROSYSTEMS COMPANY

SCb-291
Spec. 3-13
3400°F
Y.S. 4,870 psi
T.S. 6,480 psi
Elongation 255%

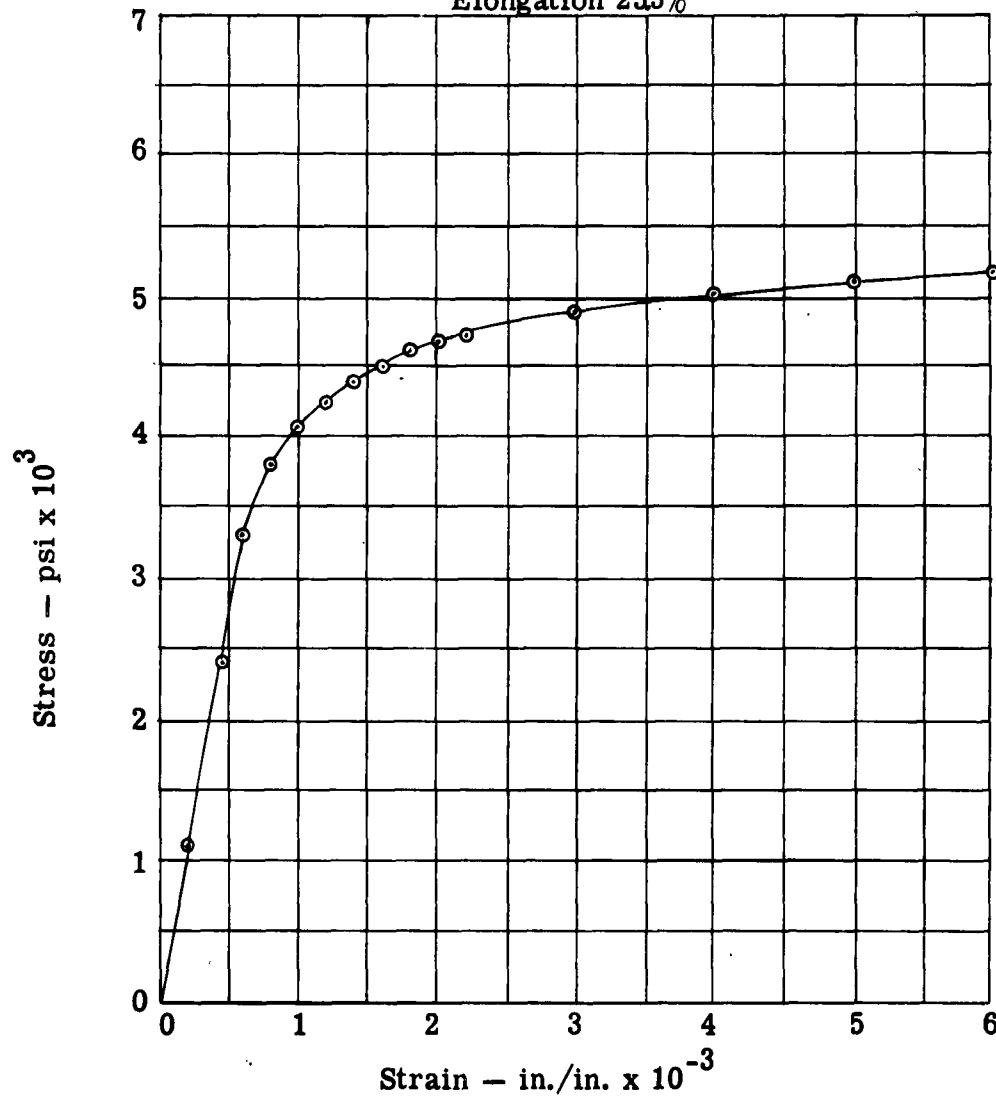


Figure 3. Stress-Strain Curve for B-33 Alloy 2750°F

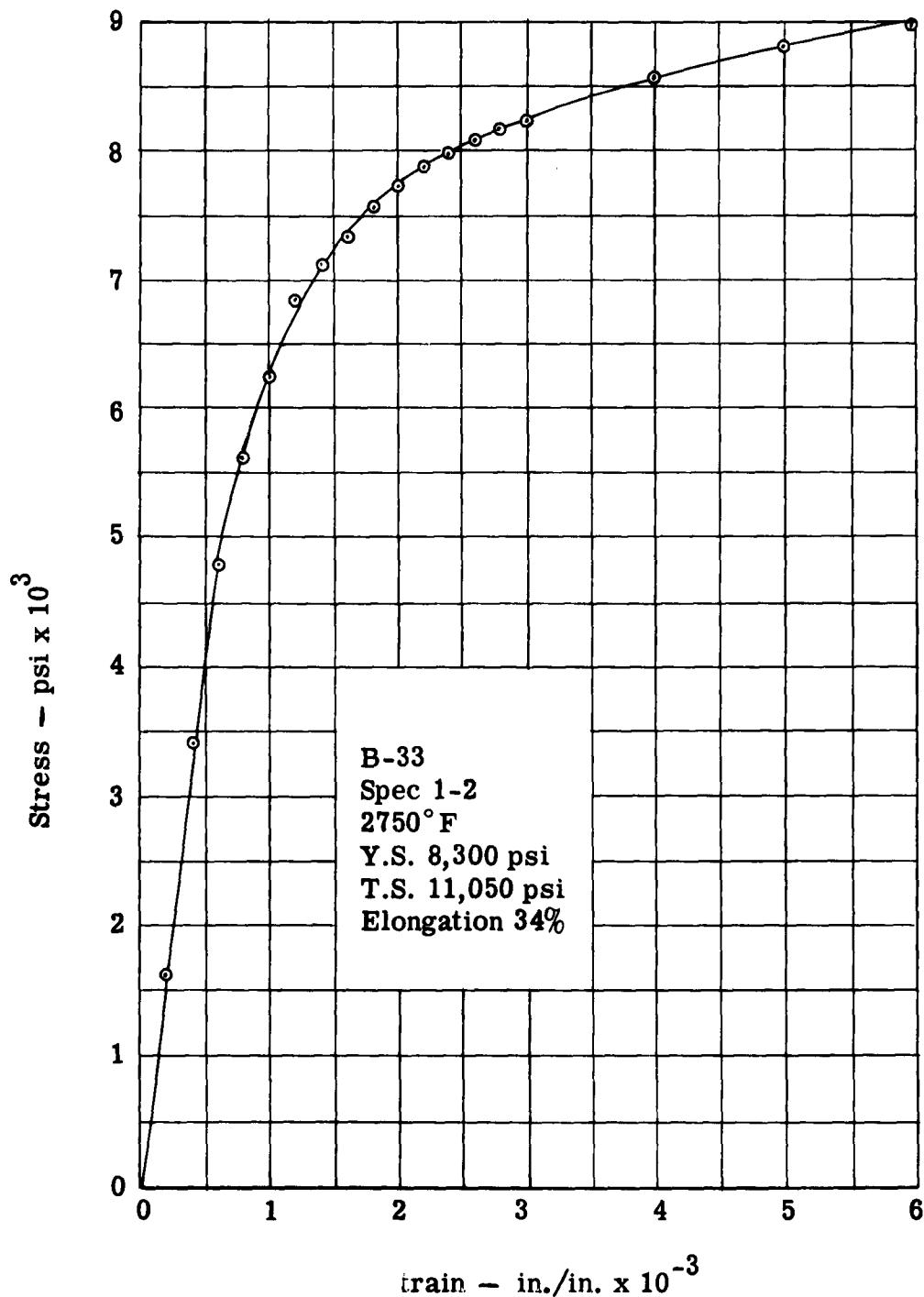


Figure 4. Stress-Strain Curve for B-33 Alloy 3100°F

B-33
Spec 2-2
3100°F
Y.S. 4030 psi
T.S. 5590 psi
Elongation 31%

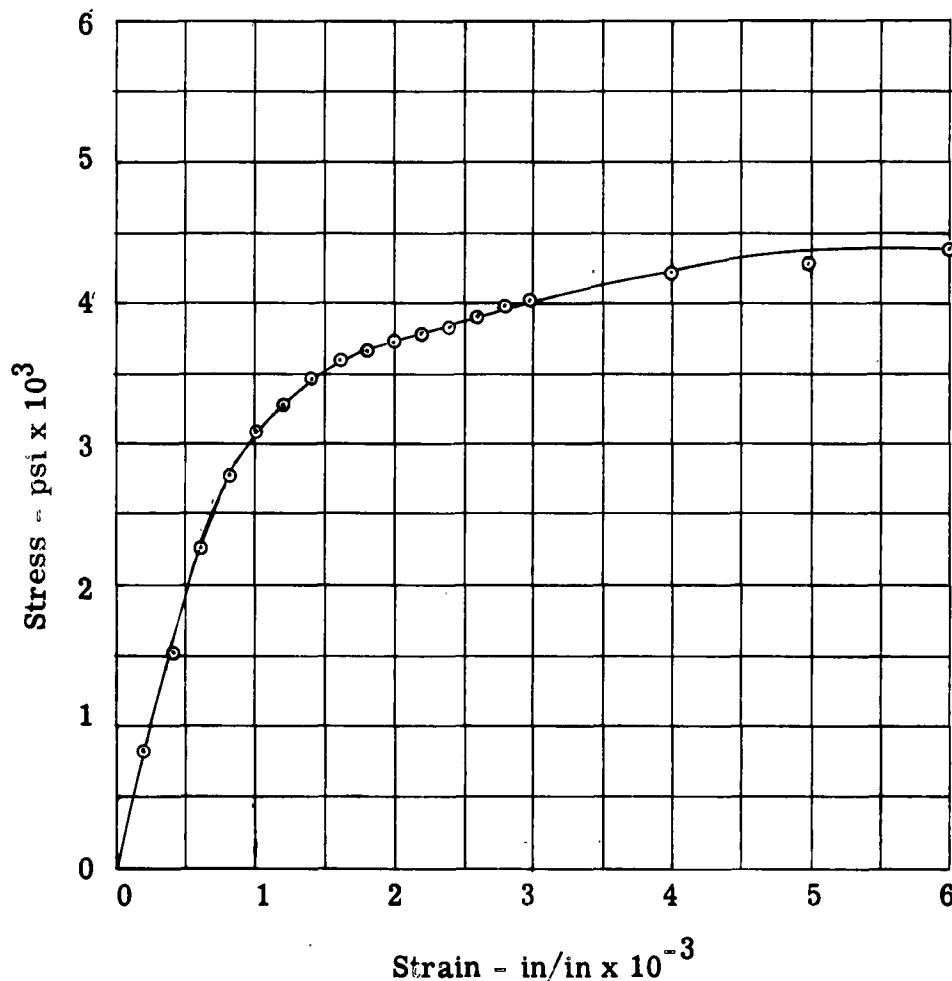


Figure 5. Stress-strain Curve for B-33 Alloy 3400°F



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B-33
Spec 2-3
3400°F
Y.S. 2400 psi
T.S. 3290 psi
Elongation 24%

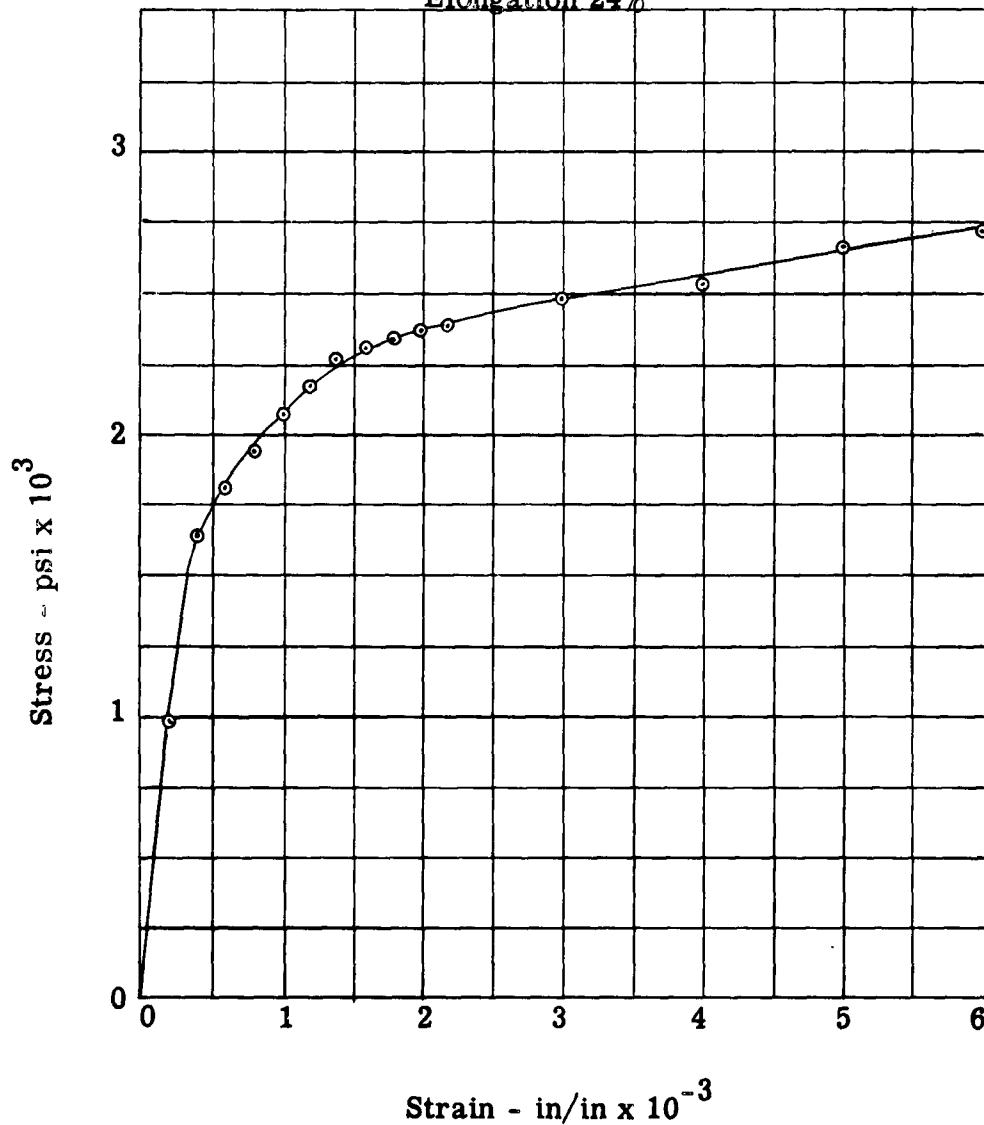


Figure 6. Stress-strain Curve for Cb-752 Alloy 3100°F

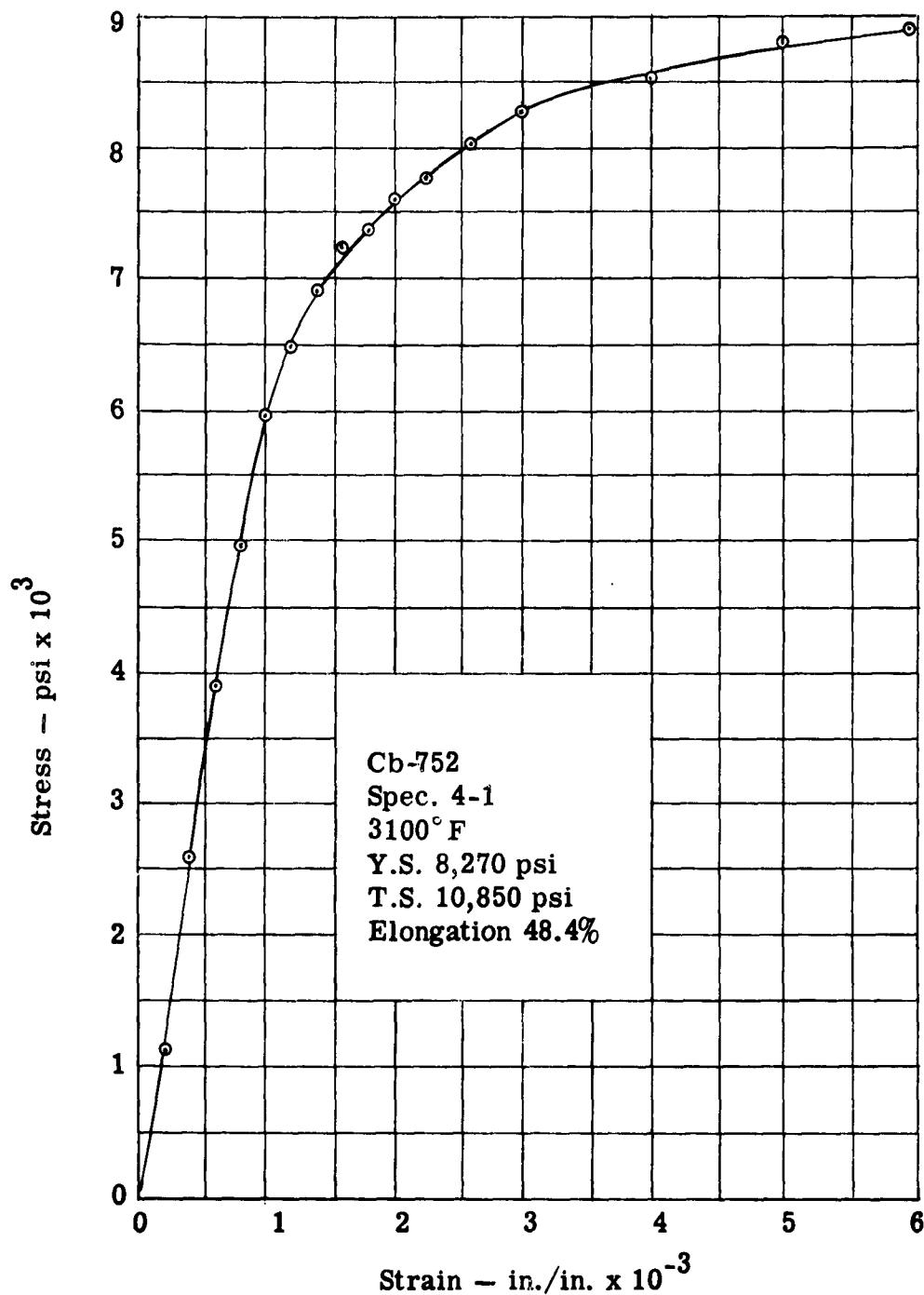


Figure 7. Stress-Strain Curve for Cb-752 Alloy 3400°F



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Cb-752
Spec 4-2
3400°F
Y.S. 5410 psi
T.S. 7050 psi
Elongation 282%

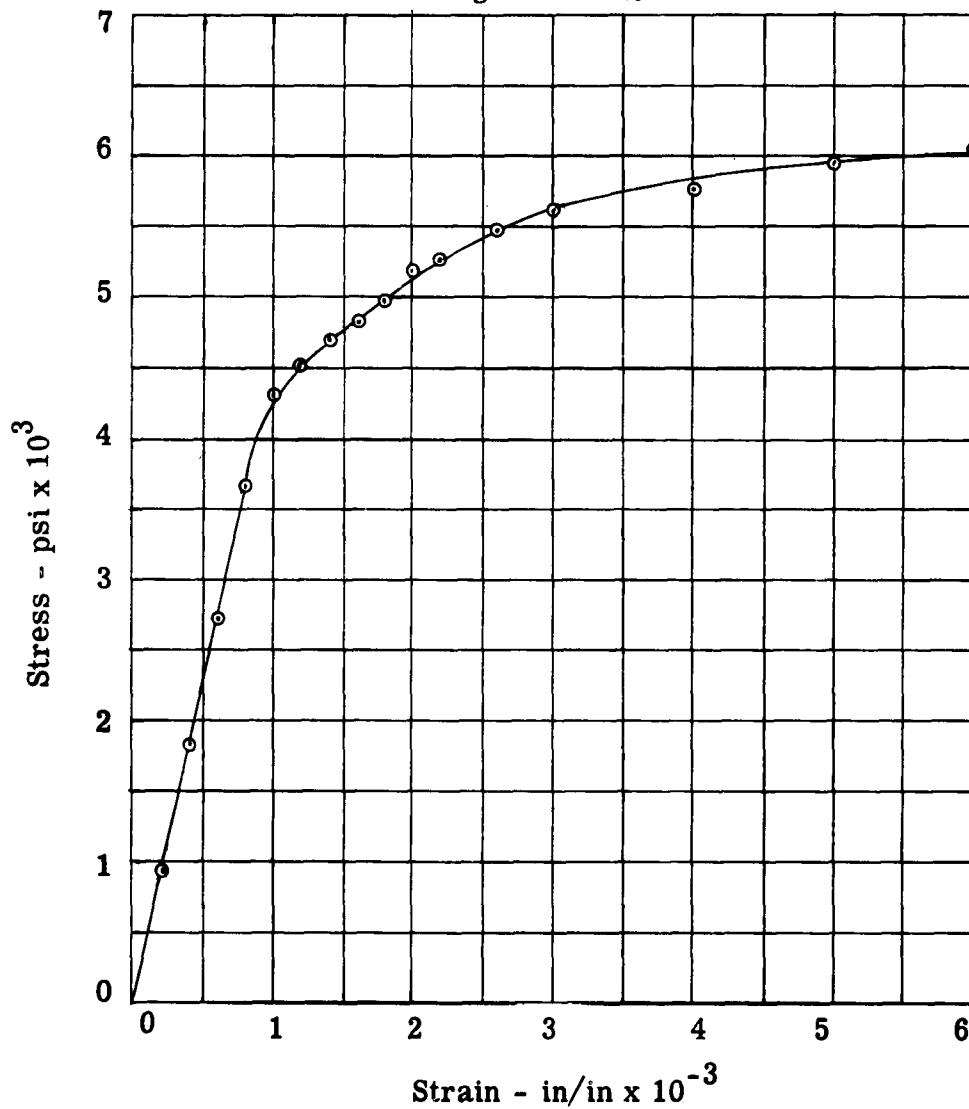


Figure 8. Stress-strain Curve for Ta-10W Alloy 3100°F

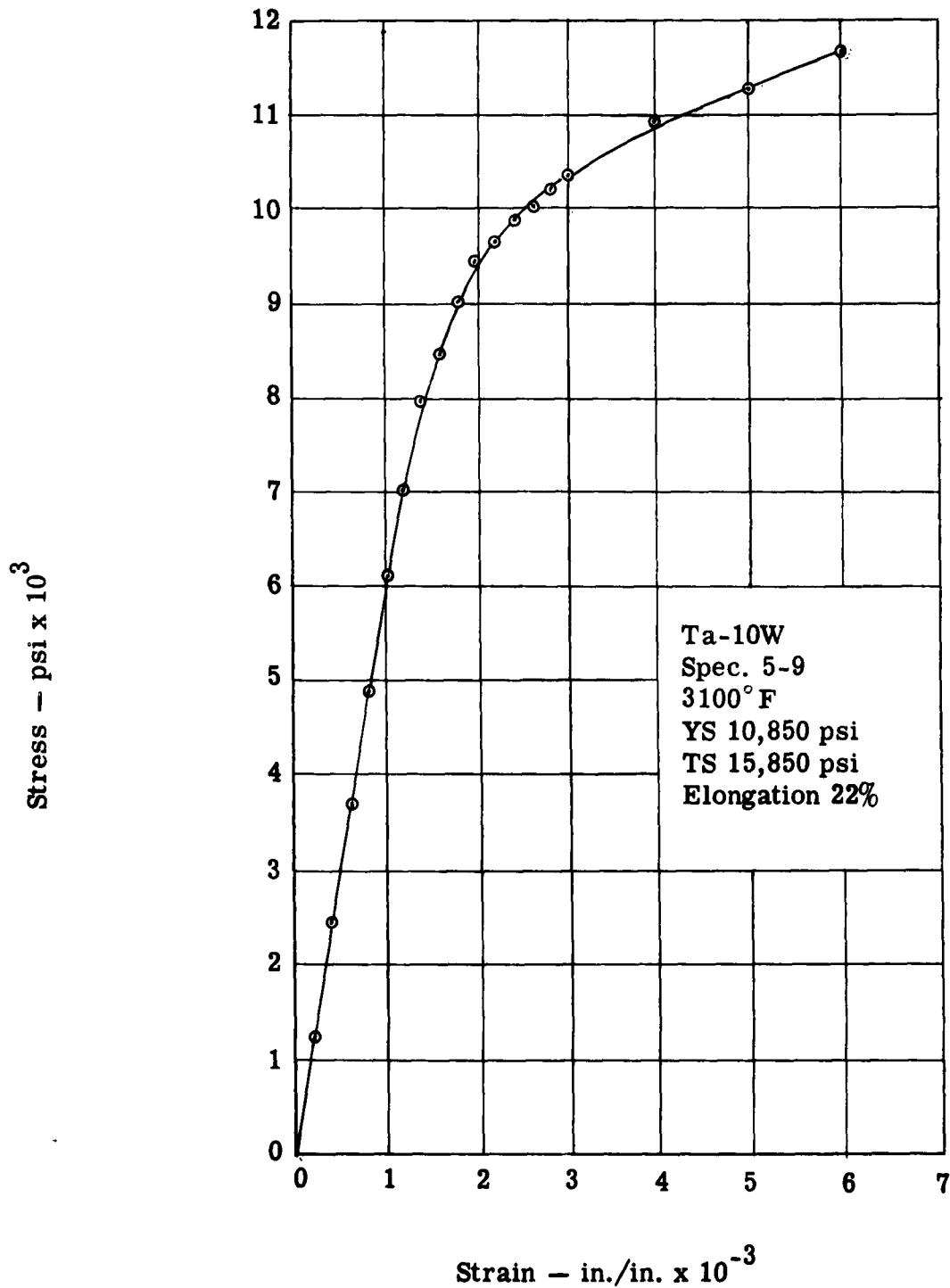


Figure 9. Stress-Strain Curve for Ti-13Cr-11V-3Al Alloy 1800°F

Ti-13Cr-11V-3A1

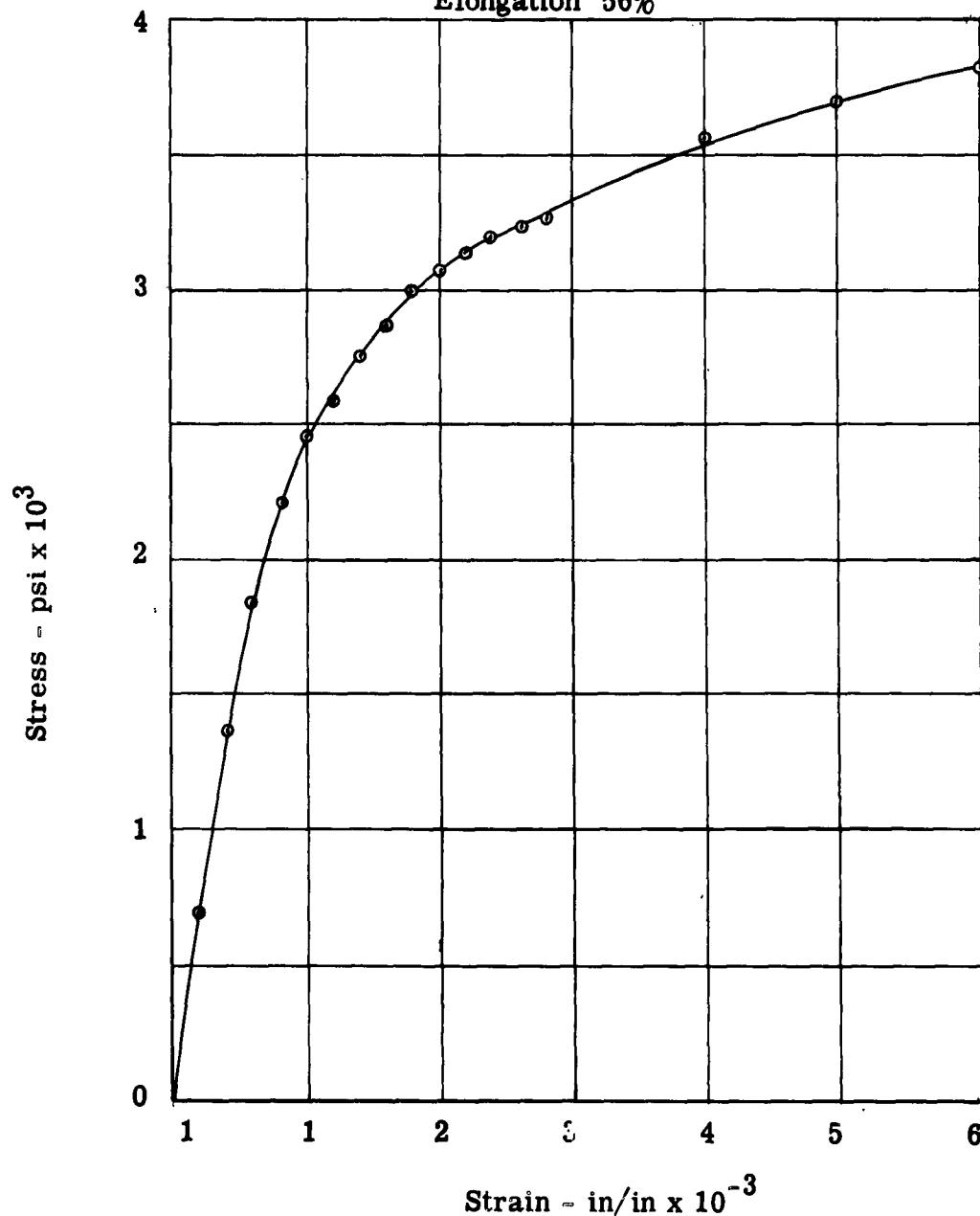
Spec 6-16

1800°F

Y.S. 3350 psi

T.S. 5230 psi

Elongation 56%



**Figure 10. Stress-Strain Curve for Ti-13Cr-11V-3A1 Alloy
2050°F**



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Ti-13Cr-11V-3Al

Spec 6-15

2050°F

Y.S. 2012 psi

T.S. 3060 psi

Elongation 69%

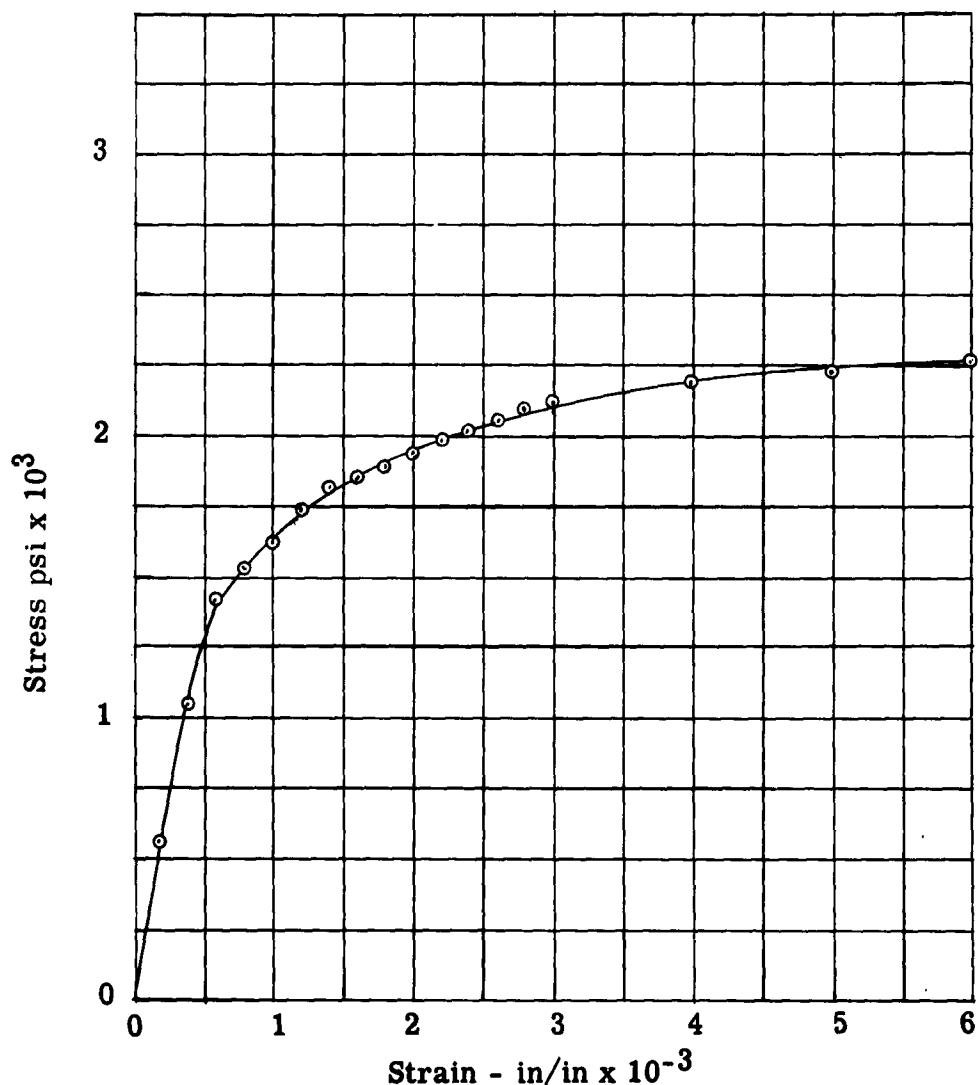


Figure 11. Stress-strain Curve for Ti-13Cr-11V-3Al Alloy 2300°F



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Ti-13Cr-11V-3Al

Spec 6-19

2300°F

Y.S. 986 psi

T.S. 1605 psi

Elongation 50%

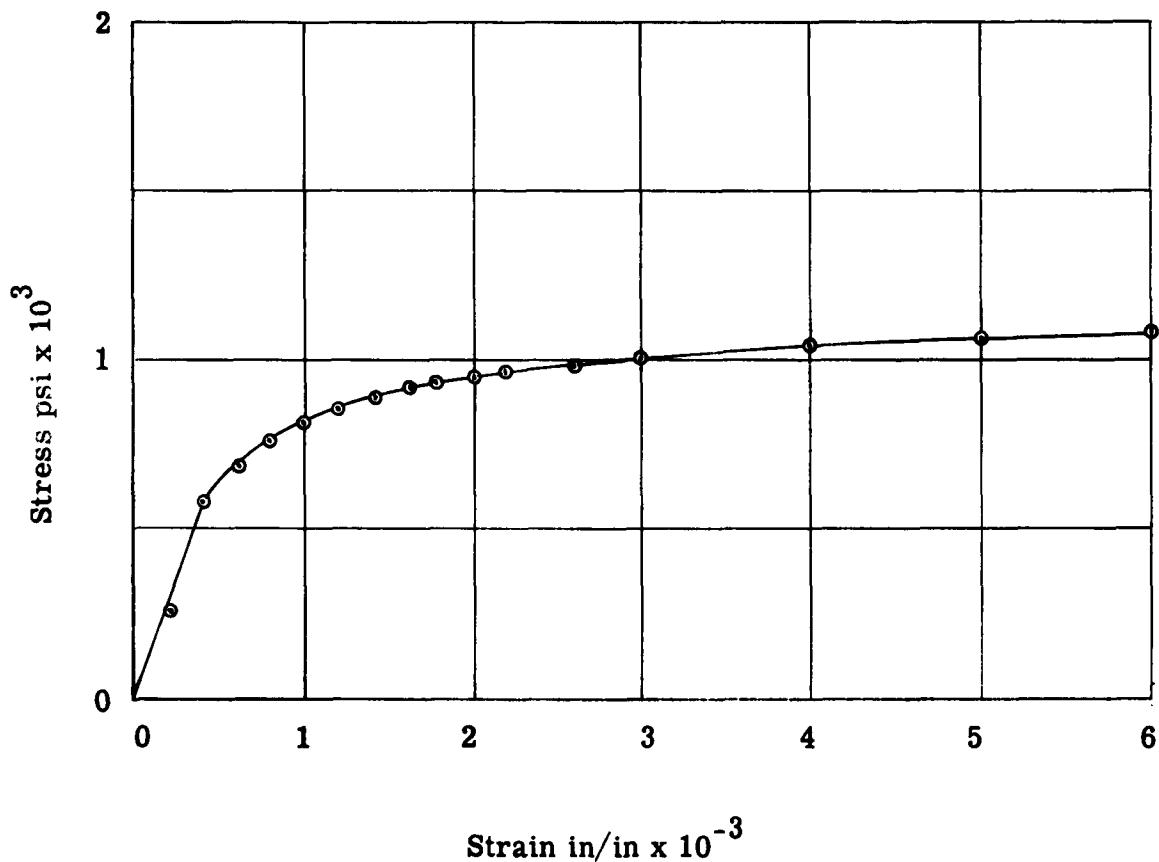


Figure 12. Creep versus Time Curve for SCb-29 Alloy 2800°F



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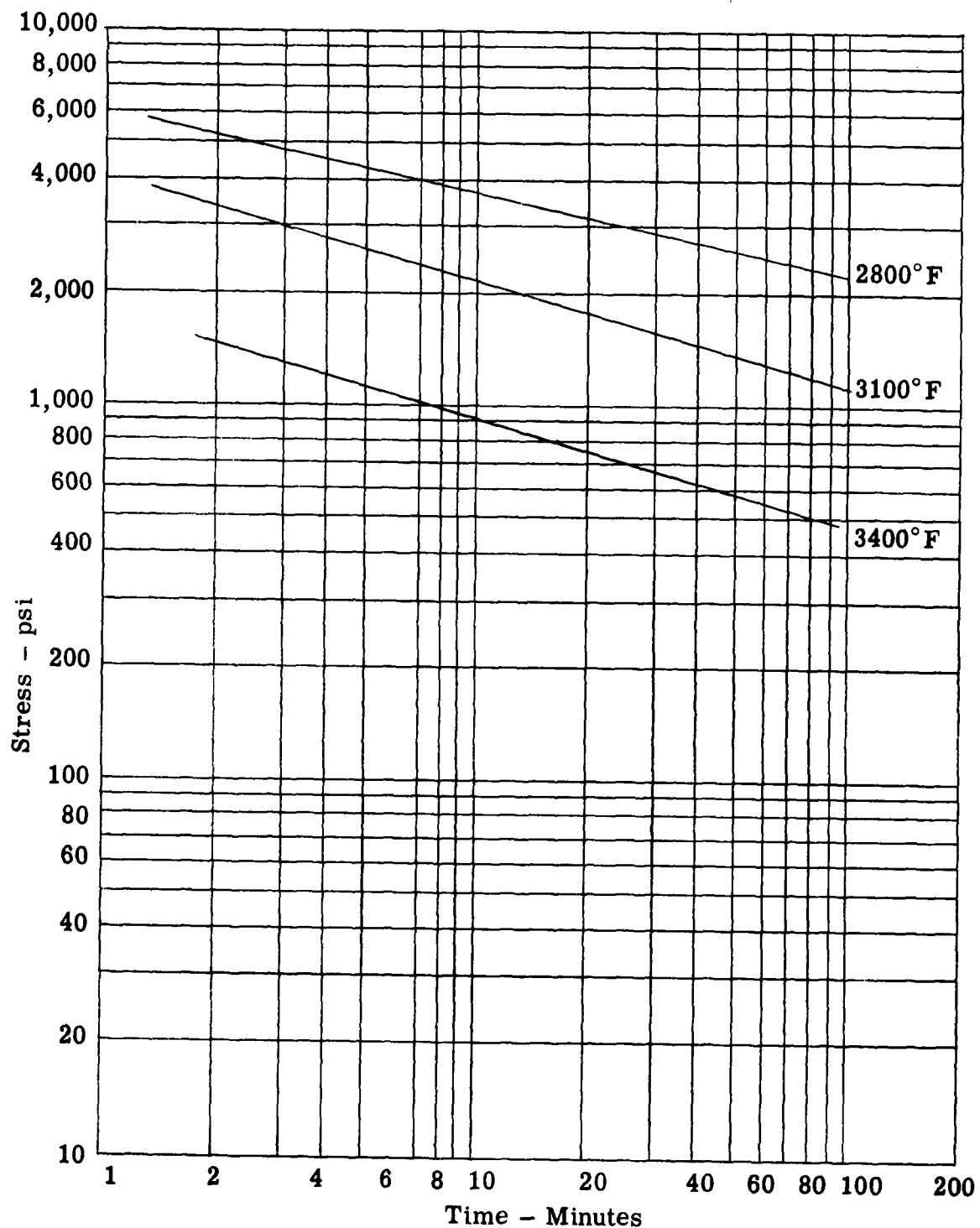


Figure 13. Time for 0.2% Creep at Various Stress Levels
SCb-291 (Alloy Cb-10Ta-10W)

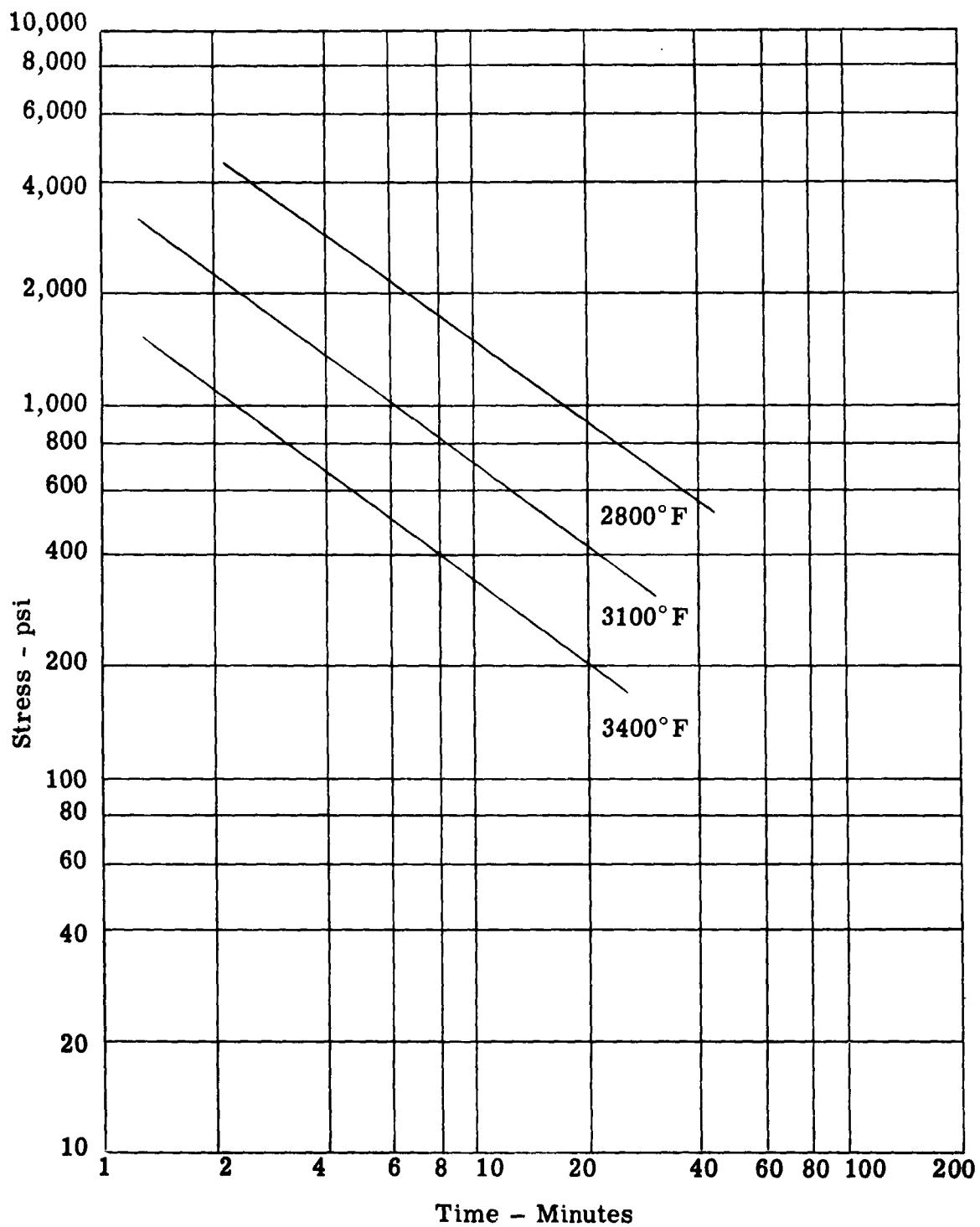


Figure 14. Time for 0.2% Creep at Various Stress Levels
Cb-752 Alloy (Cb-10W-5Zr)

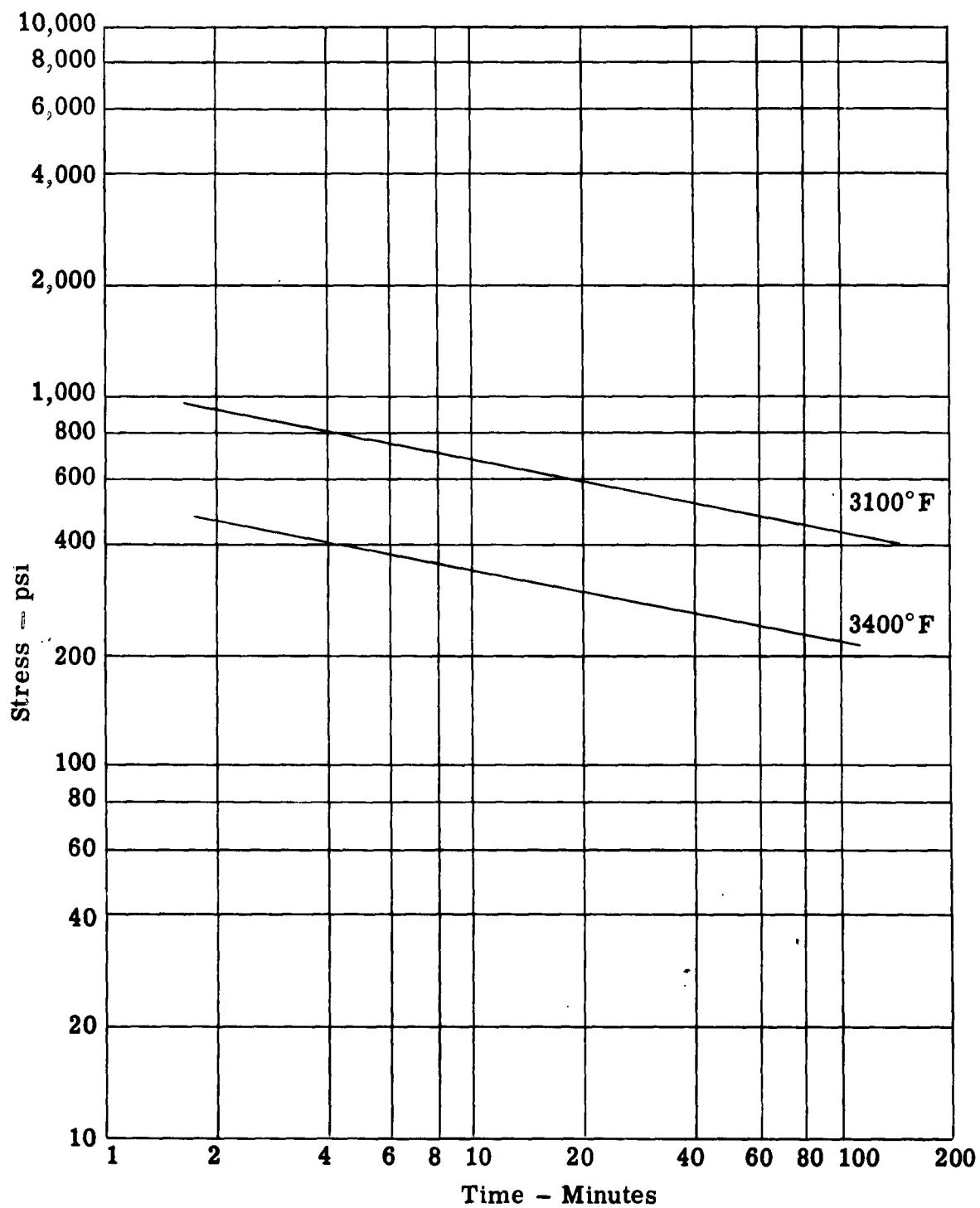


Figure 15. Time for 0.2% Creep at Various Stress Levels
B-33 Alloy (Cb-5V)

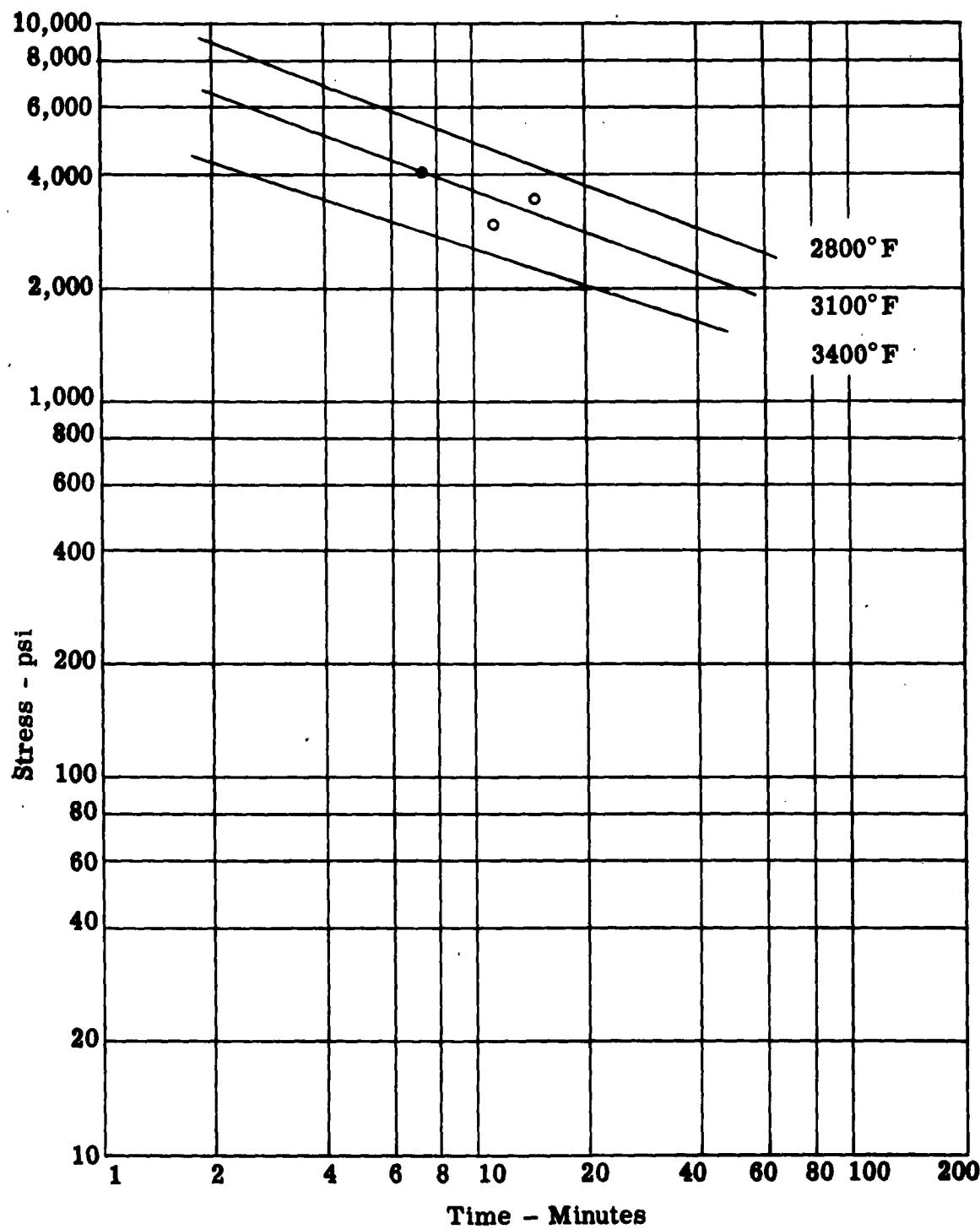
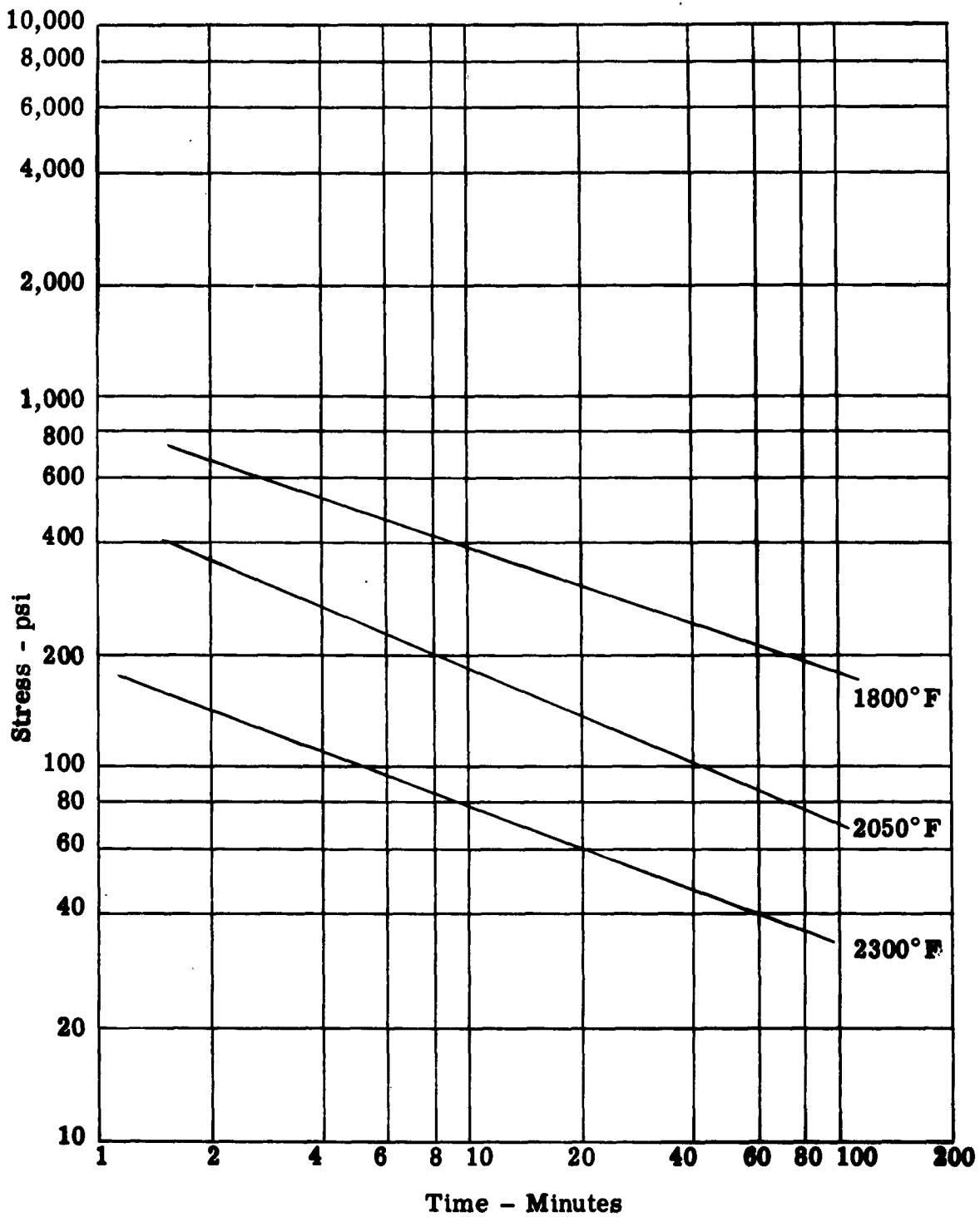


Figure 16. Time for 0.2% Creep at Various Stress Levels
Ta-10W Alloy



**Figure 17. Time for 0.2% Creep at Various Stress Levels
Ti-13 Cr-11V-3Al Alloy**

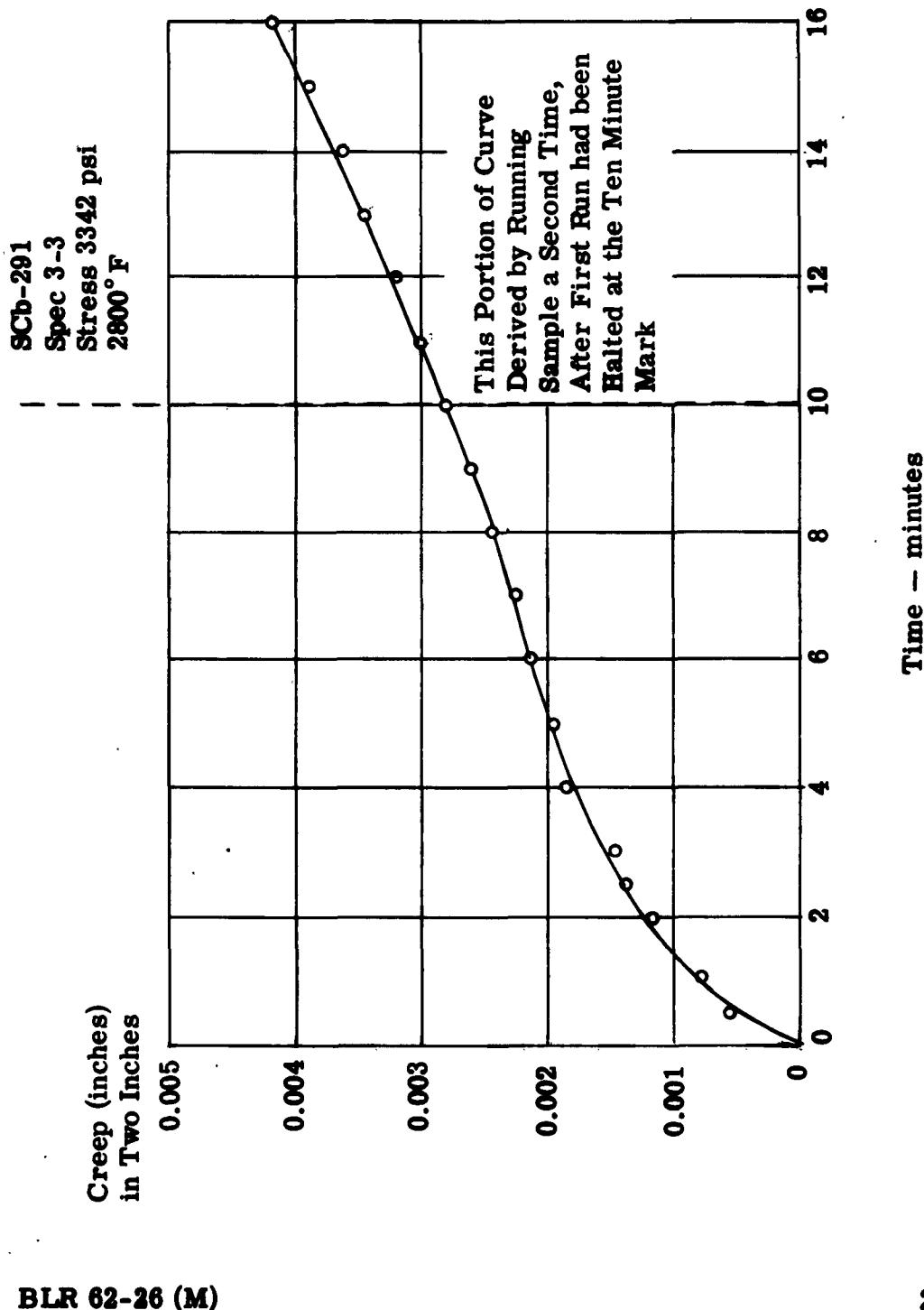
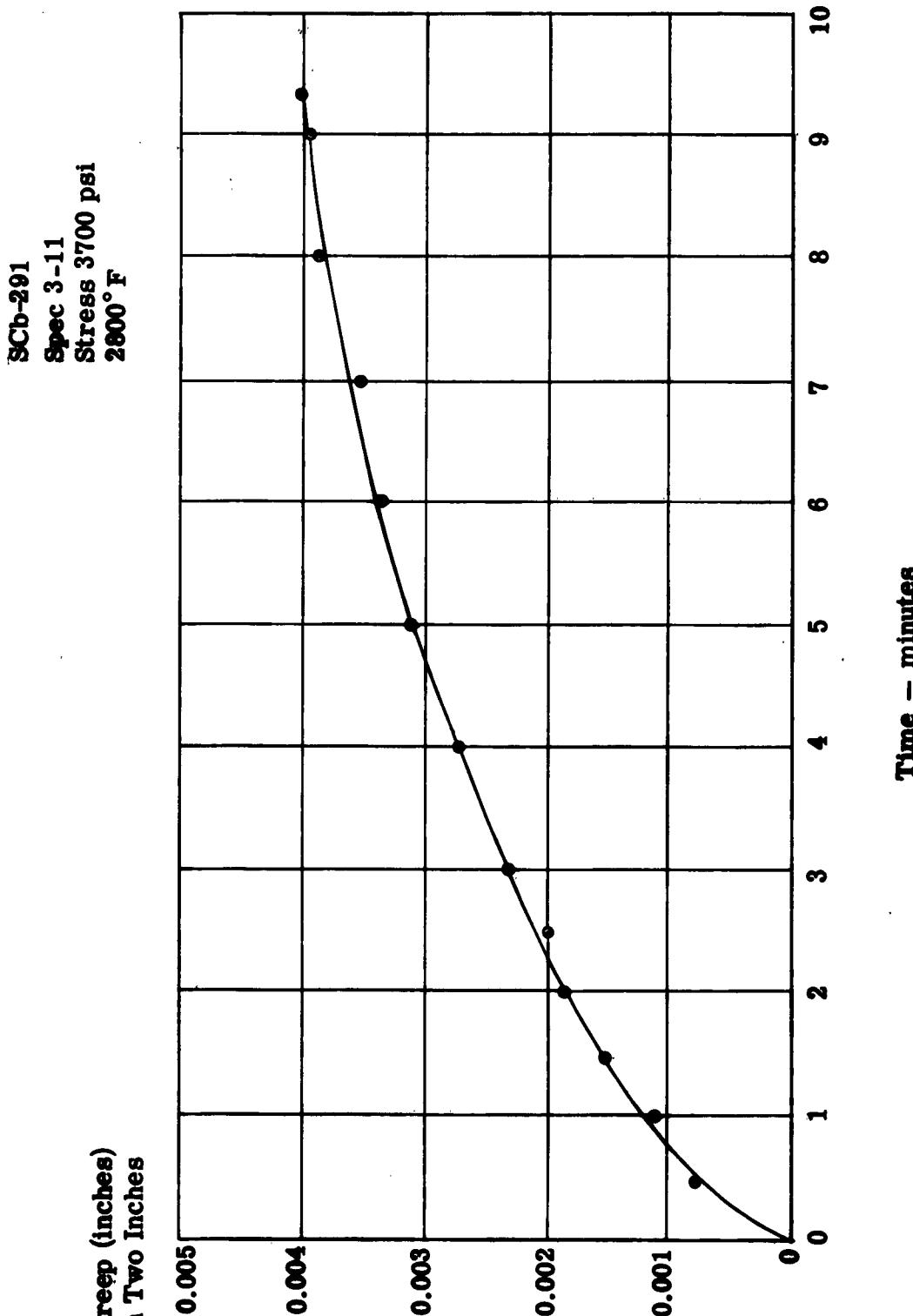


Figure 8. Stress-Strain Curve for Ta-10W Alloy 3100°F



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Figure 19. Creep Versus Time Curve for SCb-291 Alloy 2600°F

SCb-291
Spec 3-7
Stress 4020 psi
2800°F

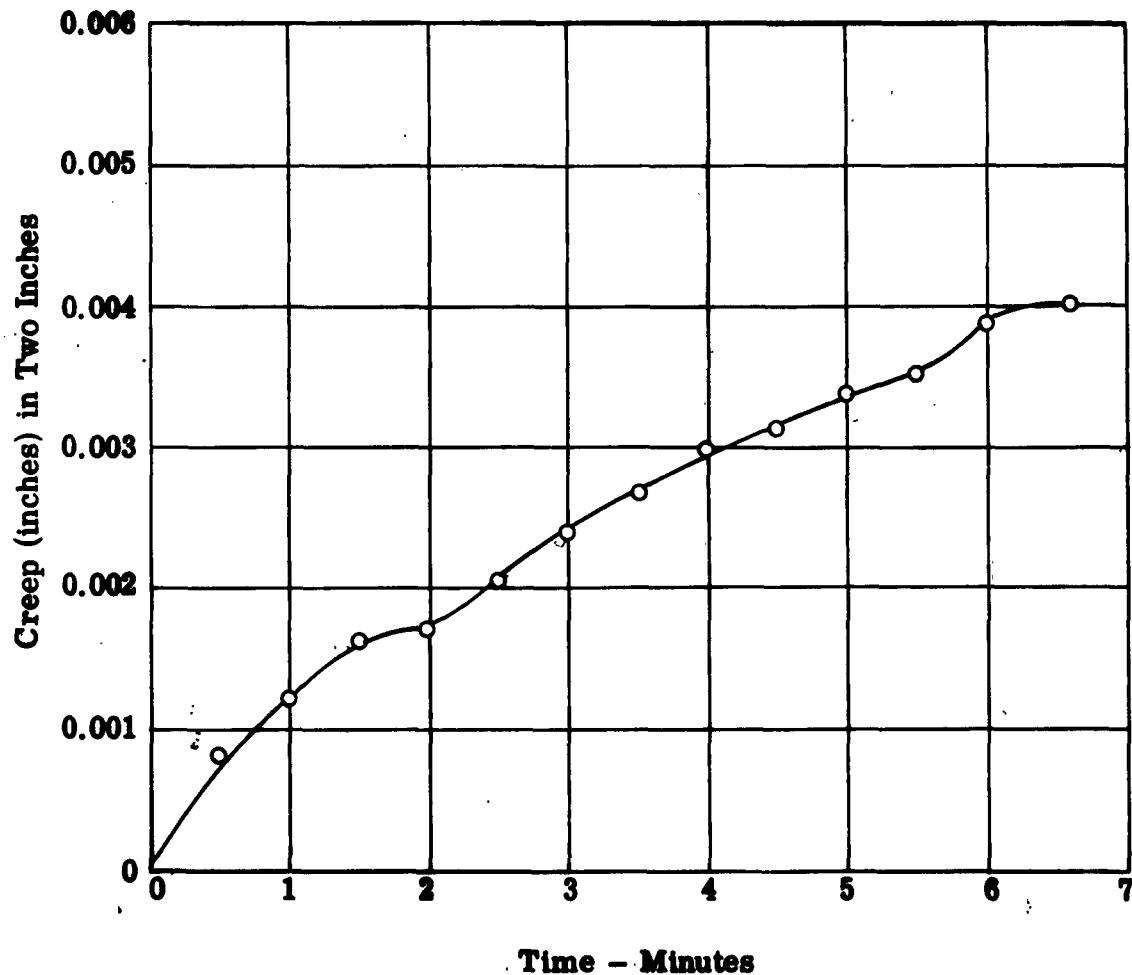


Figure 20. Creep versus Time Curve for SCb-291 Alloy 2800°F

SCb-291
Spec 3-4
Stress 1992 psi
3100°F

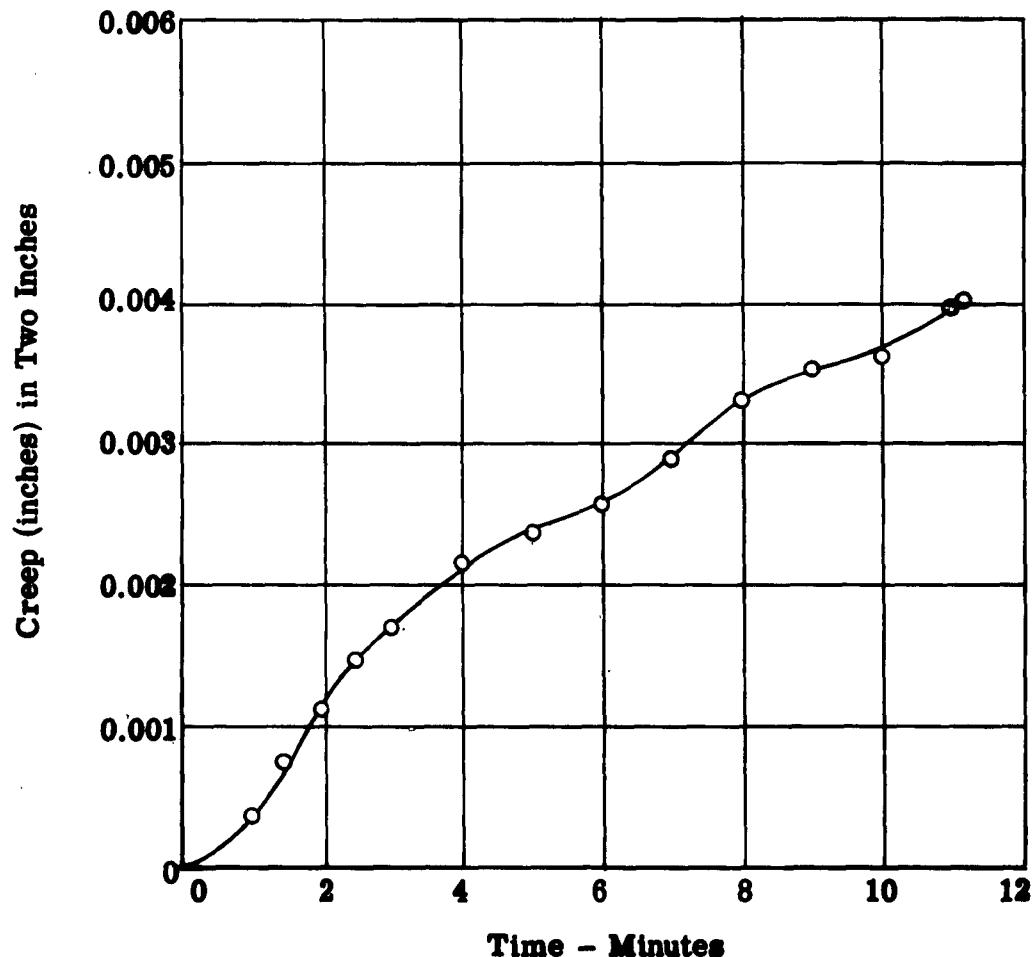
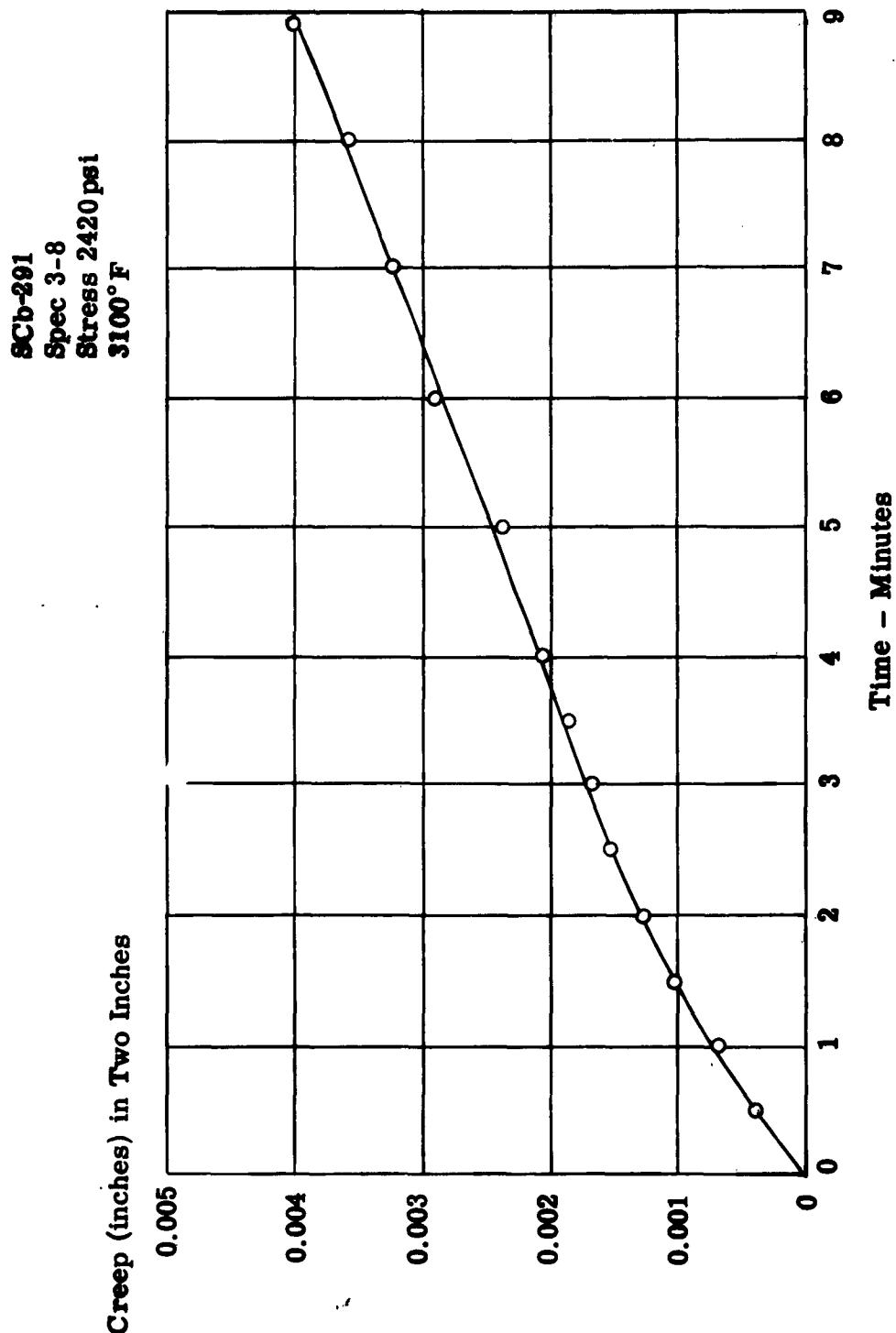


Figure 21. Creep versus Time Curve for SCb-291 Alloy 3100°F



SCb-291
Spec 3-14
Stress 1753 psi
3100°F

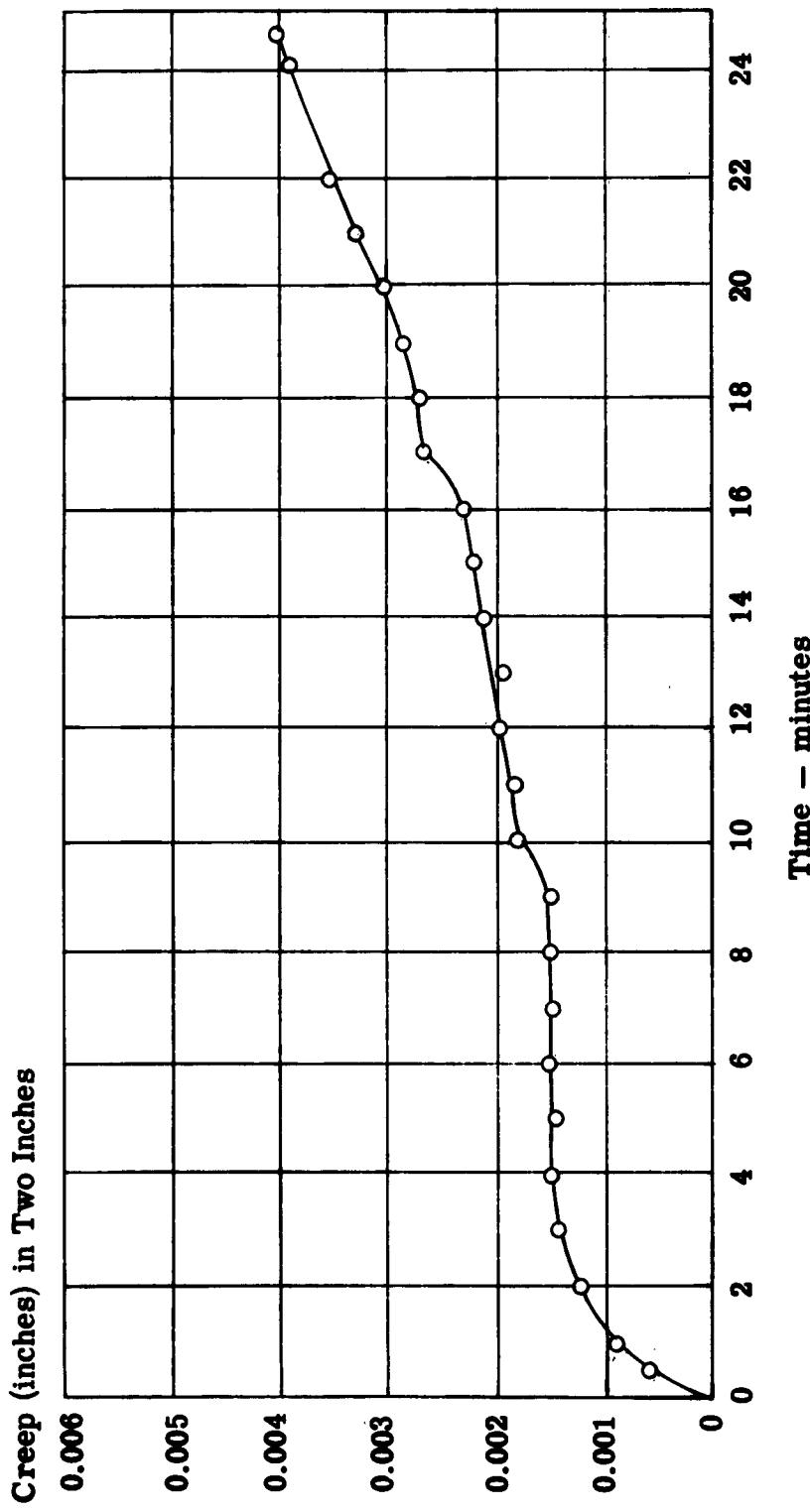


Figure 23. Creep Versus Time Curve for SCb-291 Alloy 3100°F

SCb-291
Spec 3-lb
Stress 1010 psi
3400°F

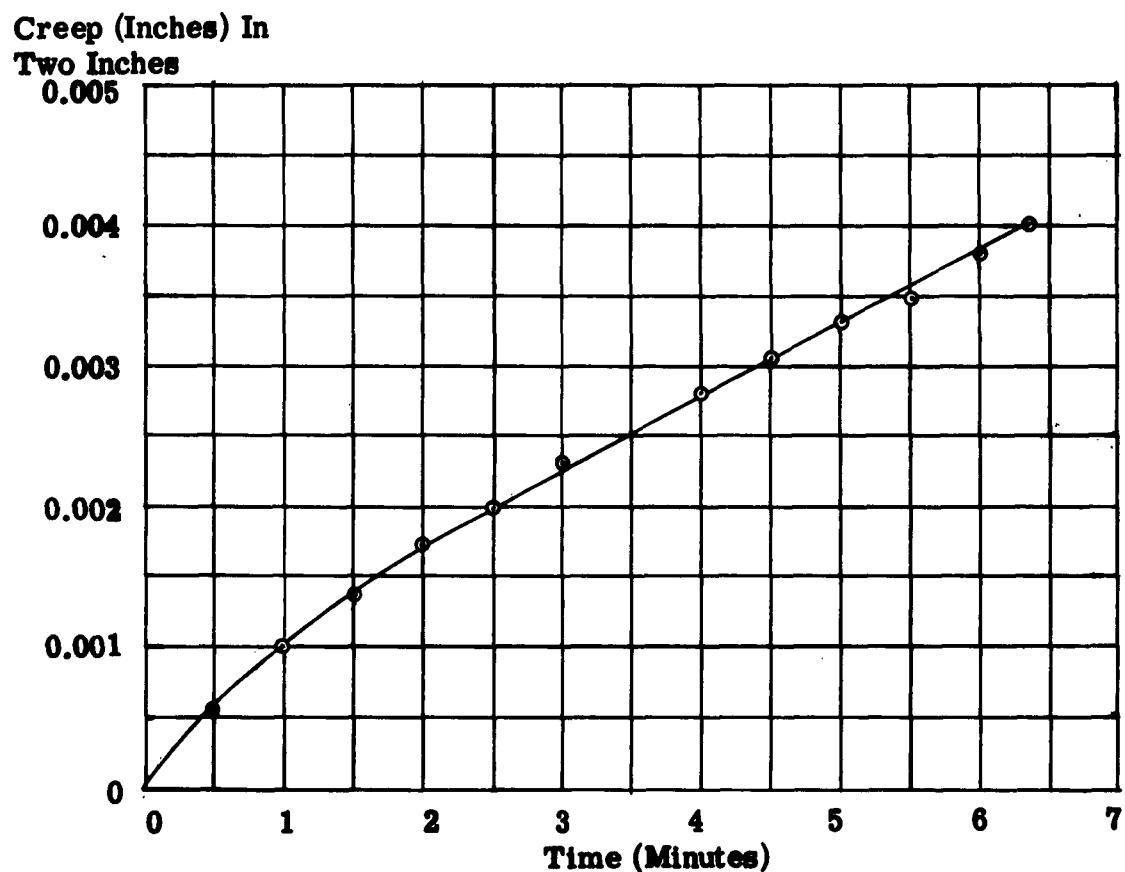


Figure 24. Creep Versus Time Curve for SCb-291 Alloy 3400°F

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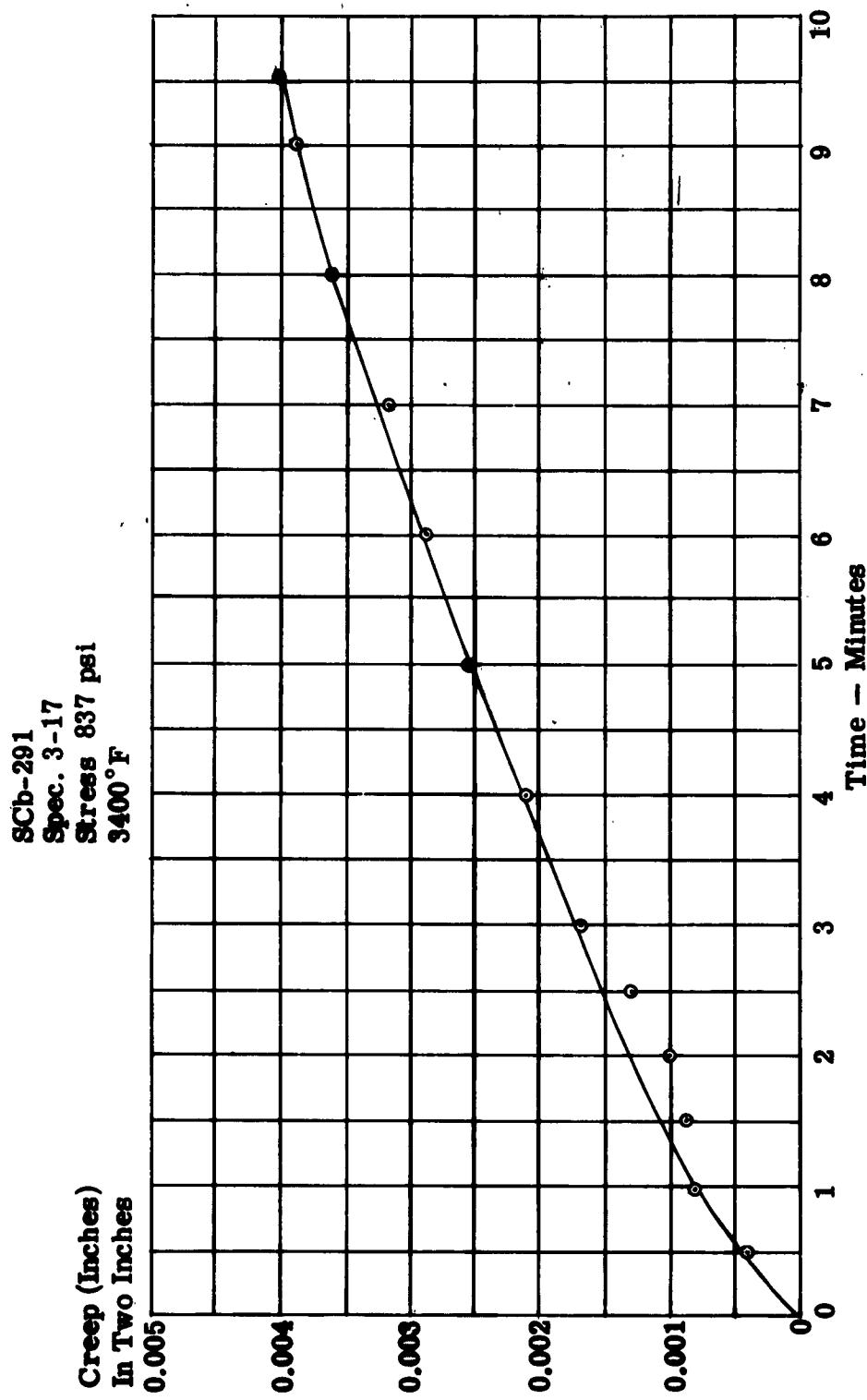


Figure 25. Creep Versus Time Curve for SCb-201 Alloy 3400-T

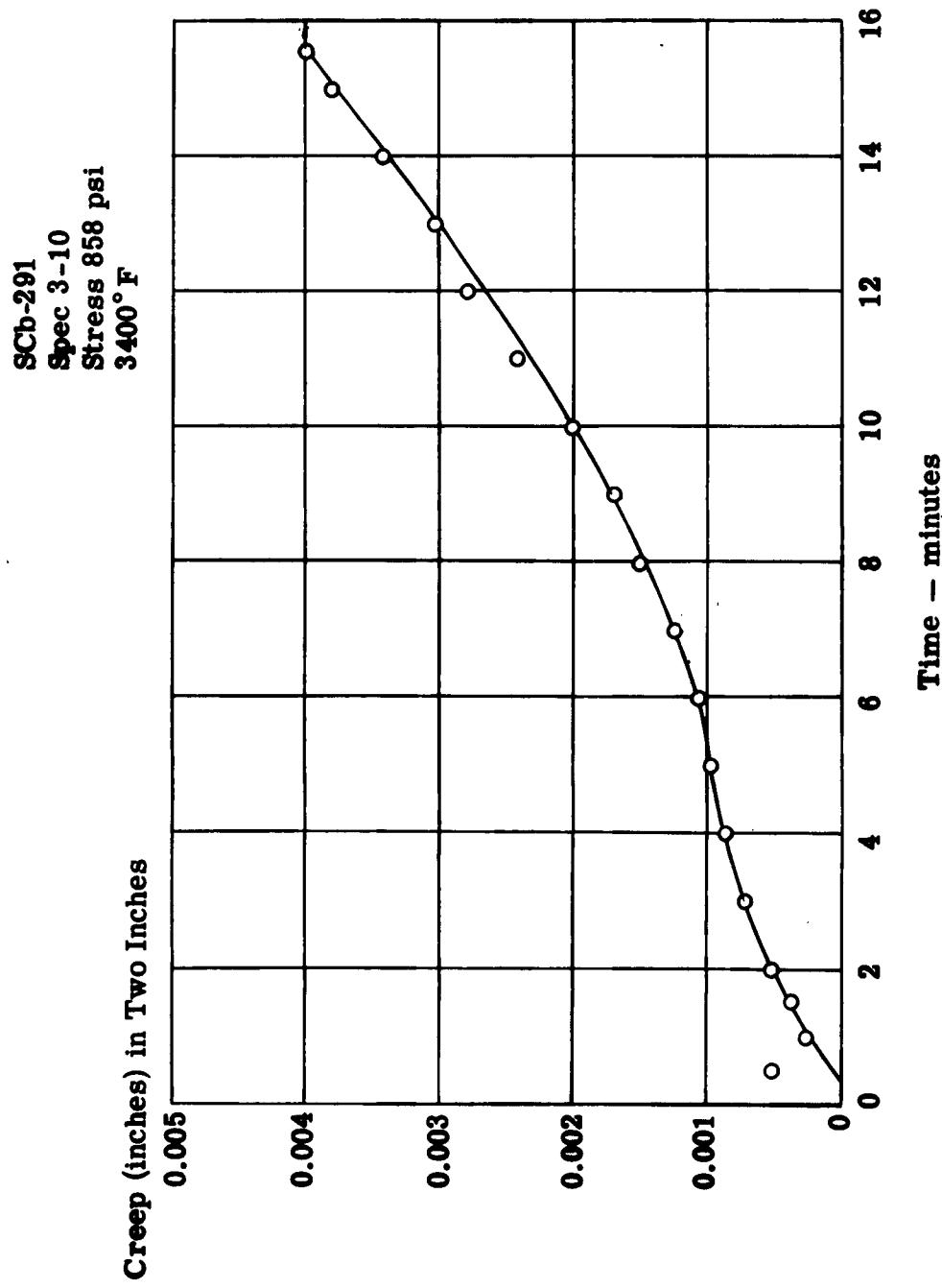


Figure 26. Creep Versus Time Curve for SCb-291 Alloy 3400°F

SCb-291
Spec 3-6
Stress 1445 psi
3400°F

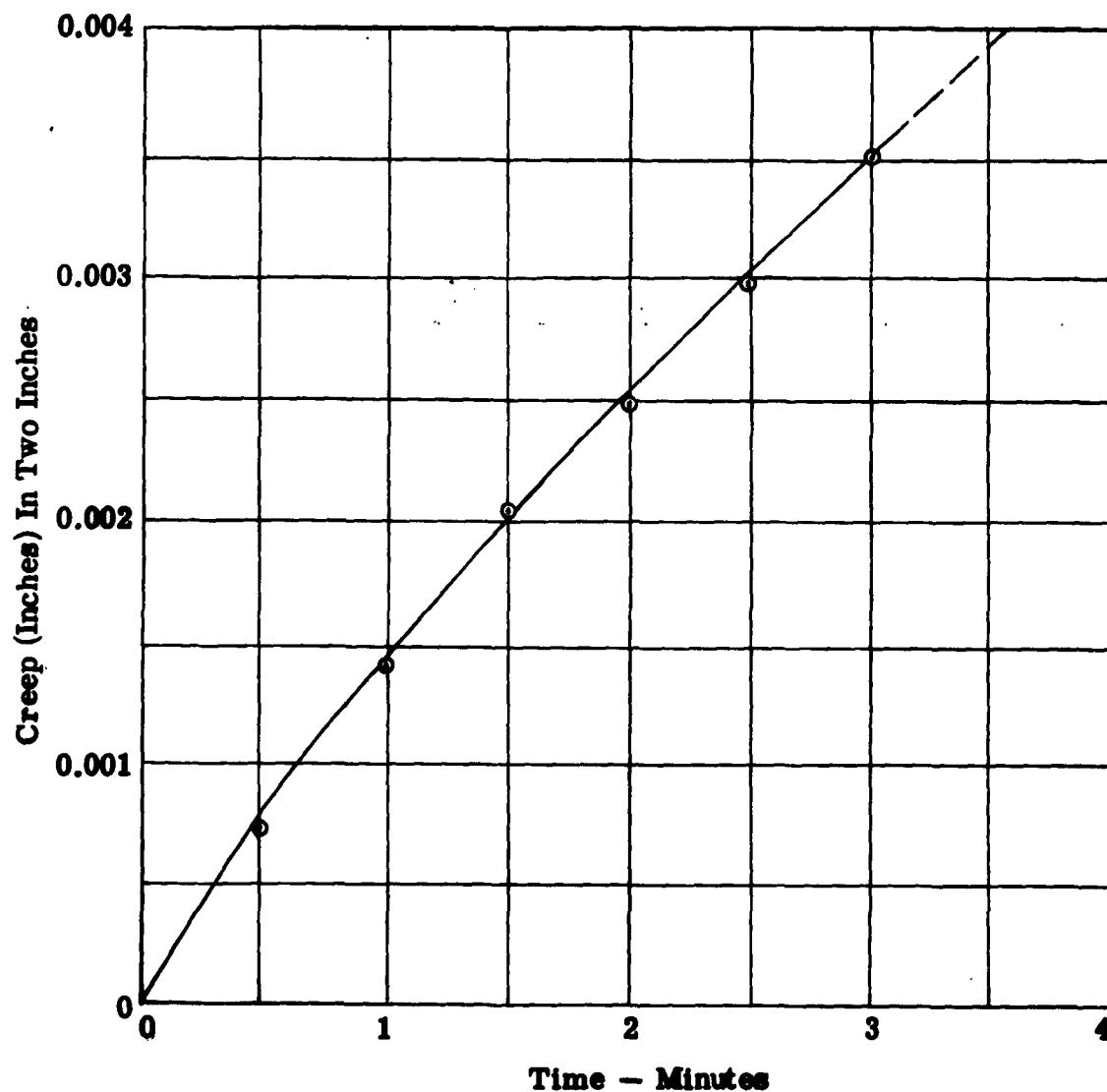
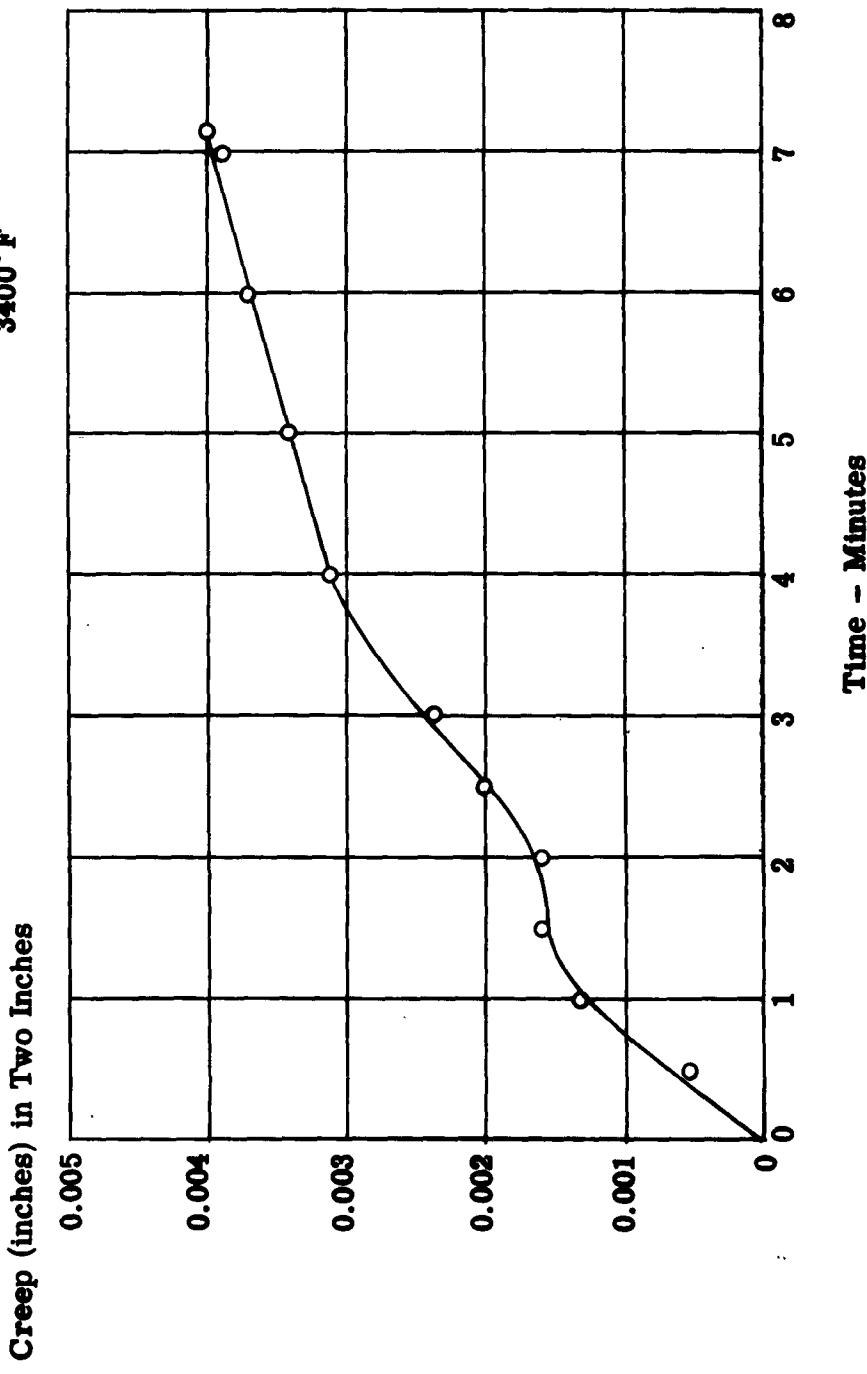


Figure 27. Creep Versus Time Curve for SCb-291 Alloy 3400°F



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SCb-291
Spec 3-18
Stress B92 psi
3400°F



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Figure 28. Creep versus Time Curve for SCb-291 Alloy 3400°F

Cb - 752
Spec 4-8
Stress 1300 psi
2800°F

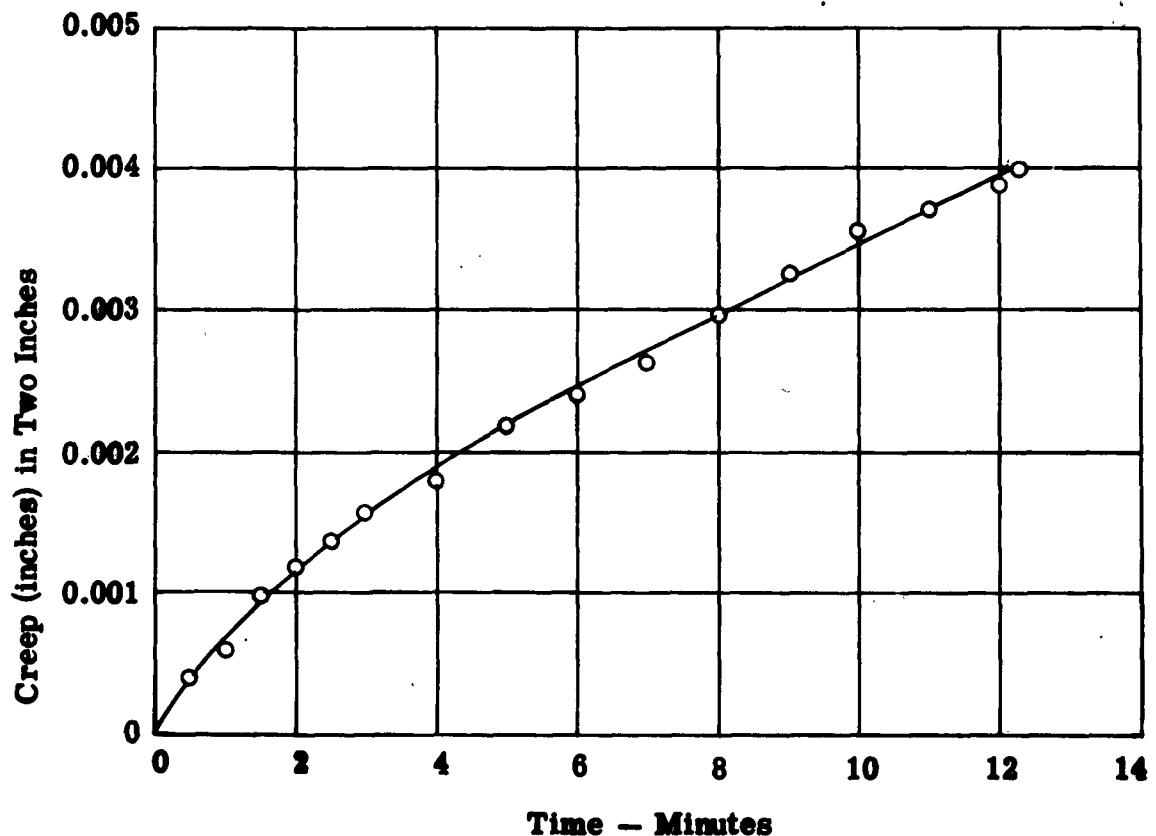


Figure 29. Creep Versus Time Curve for Cb-752 Alloy 2800°F



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Cb - 752
Spec 4-7 (Transverse)
Stress 1380 psi
2800°F

Creep (inches) In Two Inches

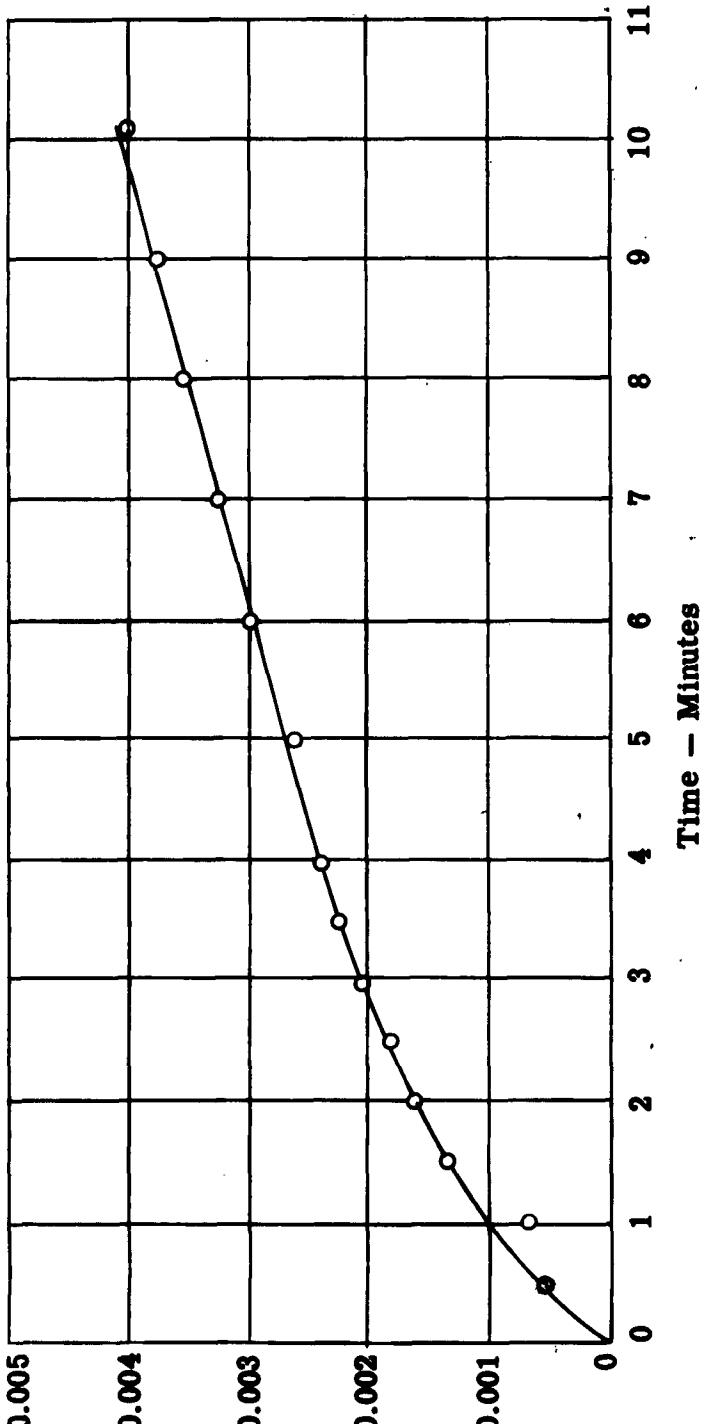


Figure 30. Creep Versus Time Curve for Cb-752 Alloy 2800°F

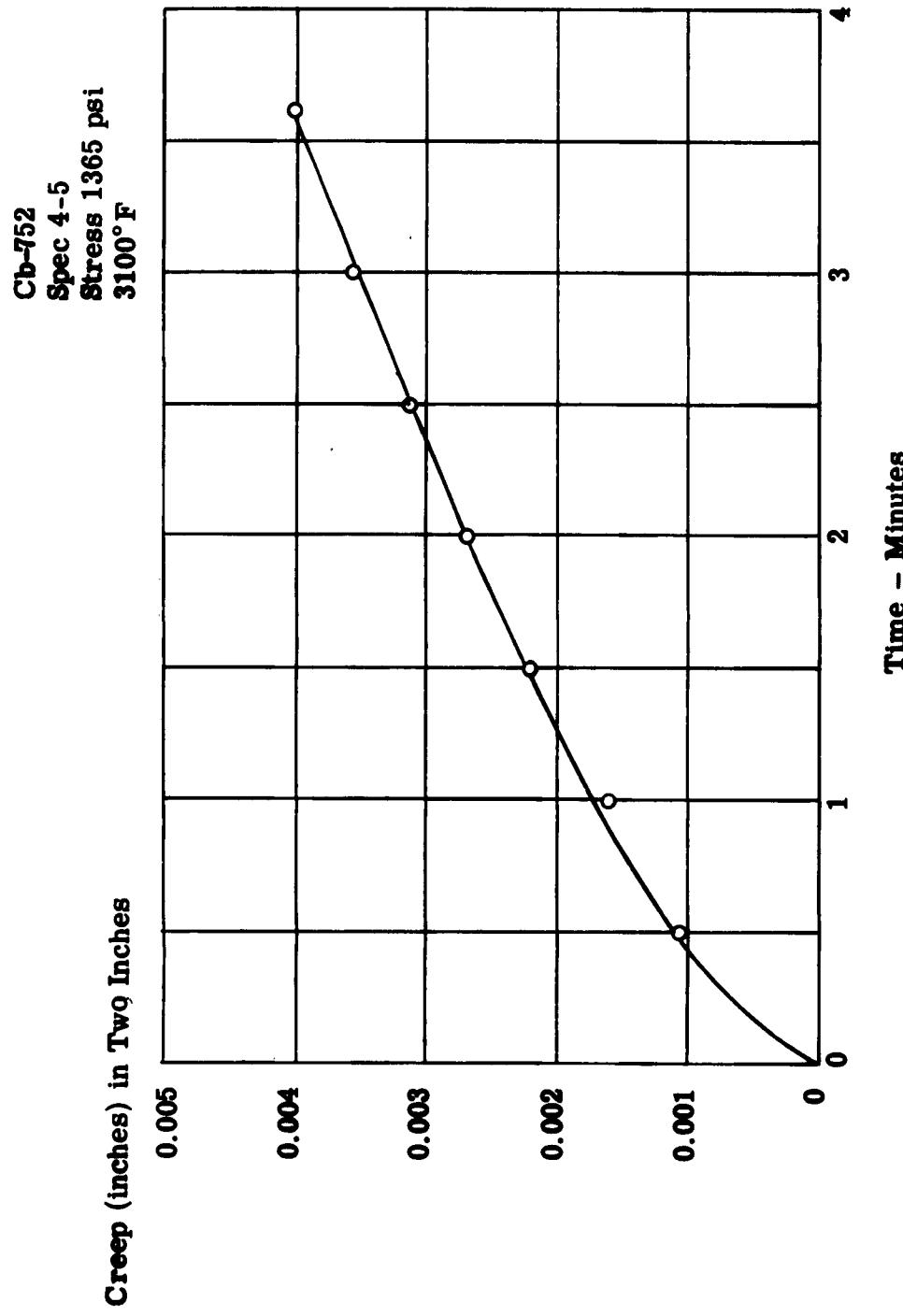


Figure 31. Creep Versus Time Curve For Cb-752 Alloy 3100°F

Cb - 752
Spec. 4-3
Stress 2520 Psi
3100°F

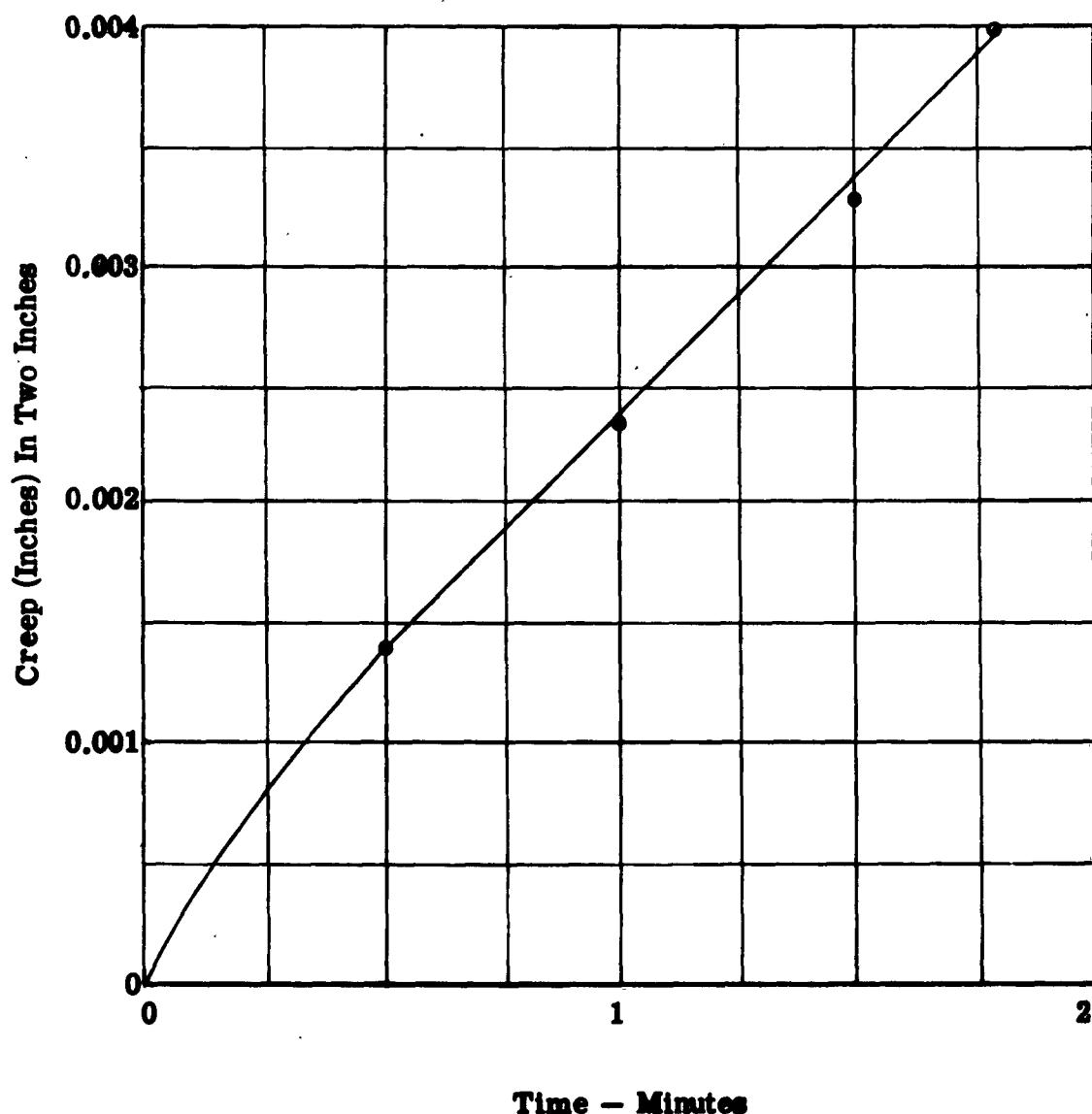
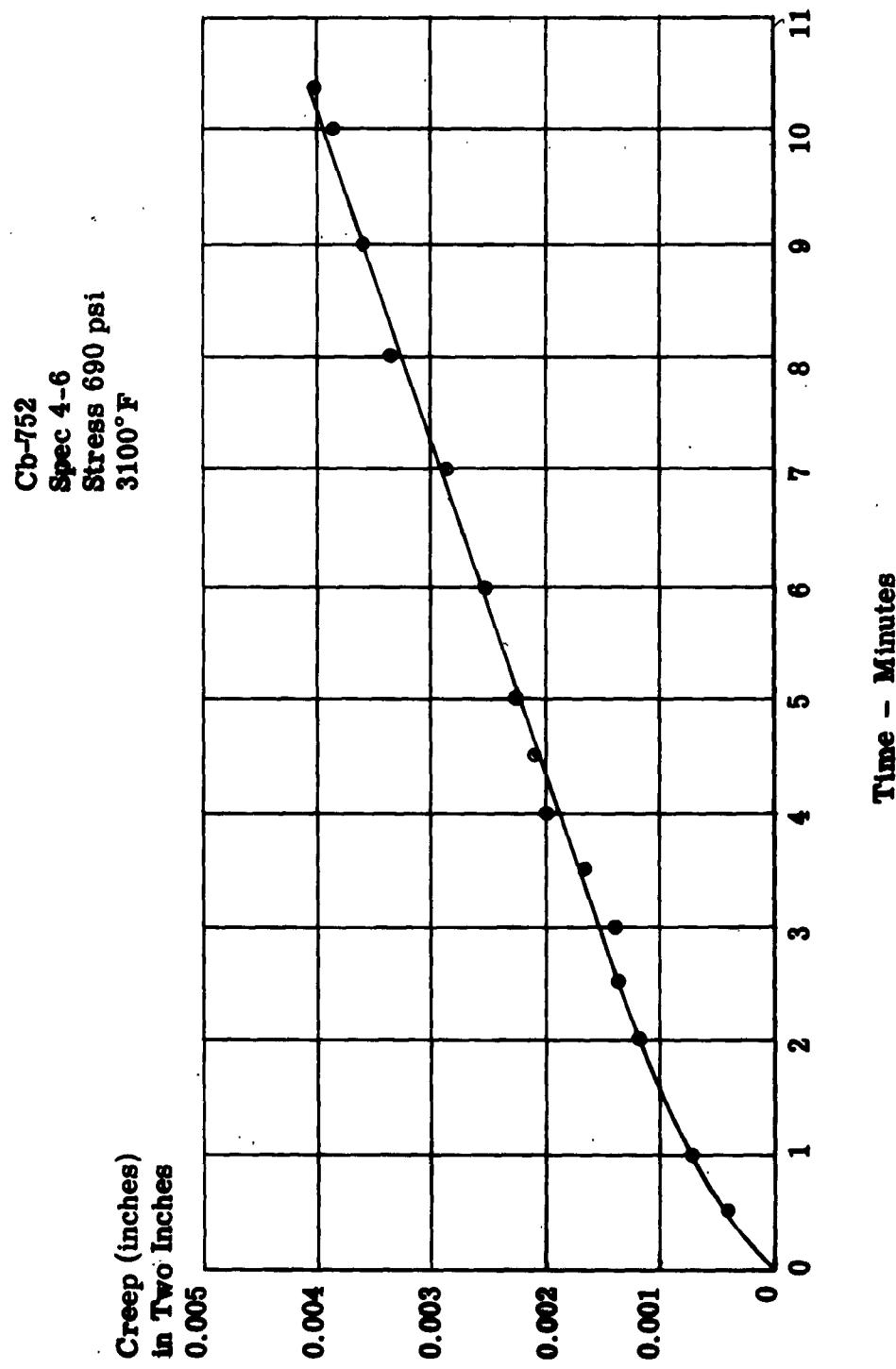


Figure 32. Creep Versus Time Curve for Cb-752 Alloy 3100°F



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Figure 33. Creep Versus Time Curve For Cb-752 Alloy 3100°F

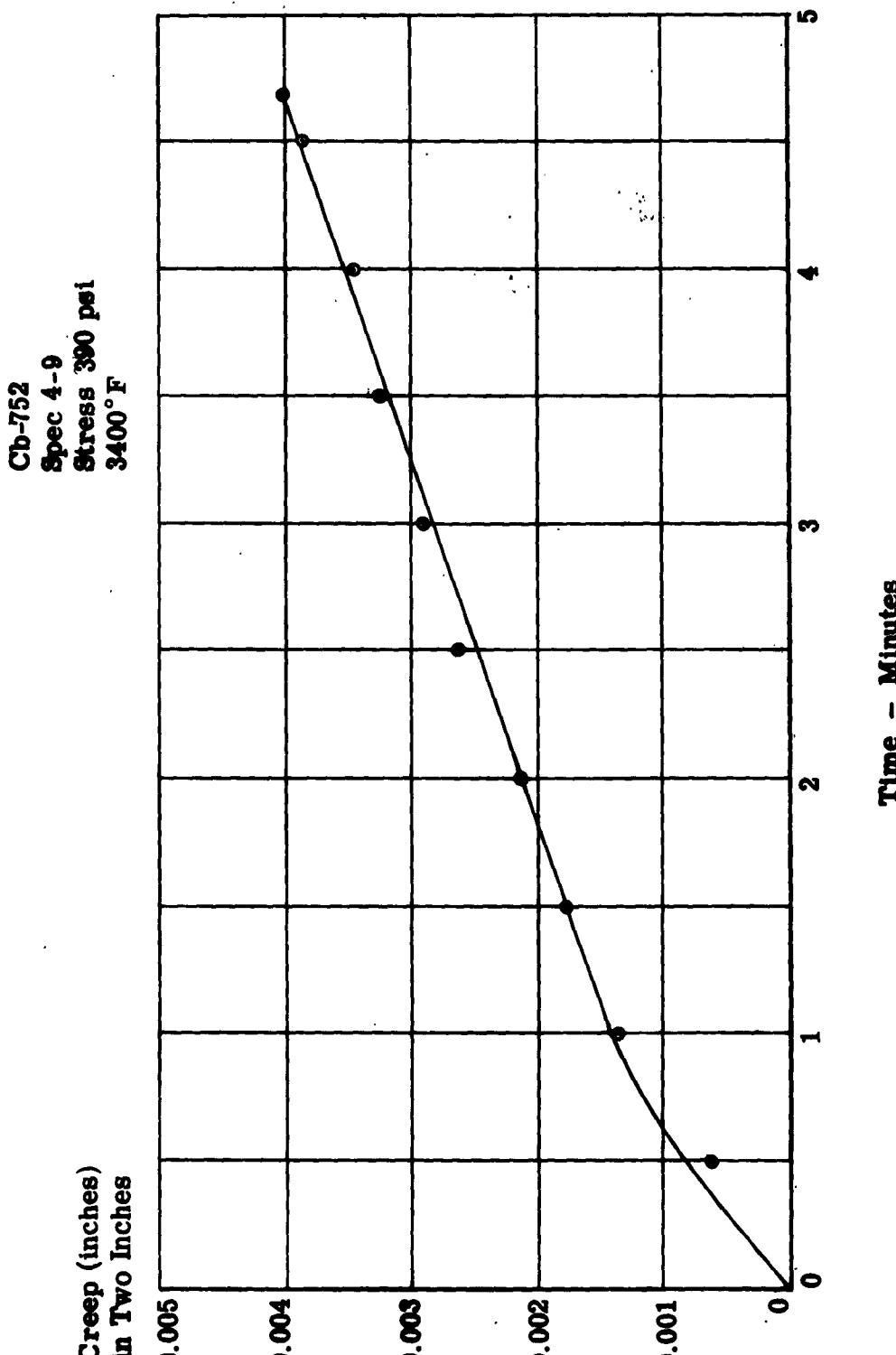


Figure 34. Creep versus Time Curve for CB-752 Alloy 3400°F

Cb - 752
Spec. 4-4
Stress 945 psi
3400°F

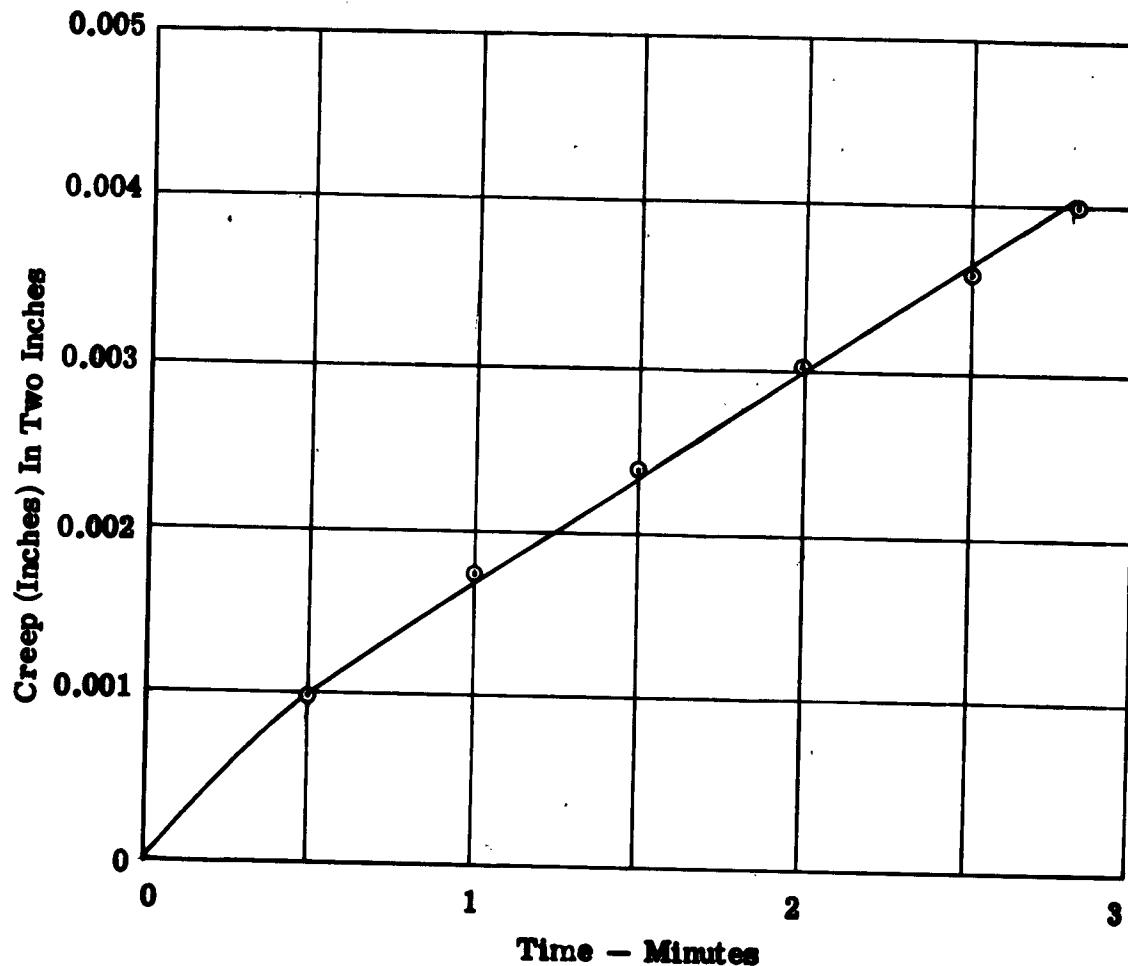


Figure 35. Creep Versus Time Curve for Cb-752 Alloy 3400°F

**Ta-10W
Spec 5-11
Stress 4010 psi
2800°F**

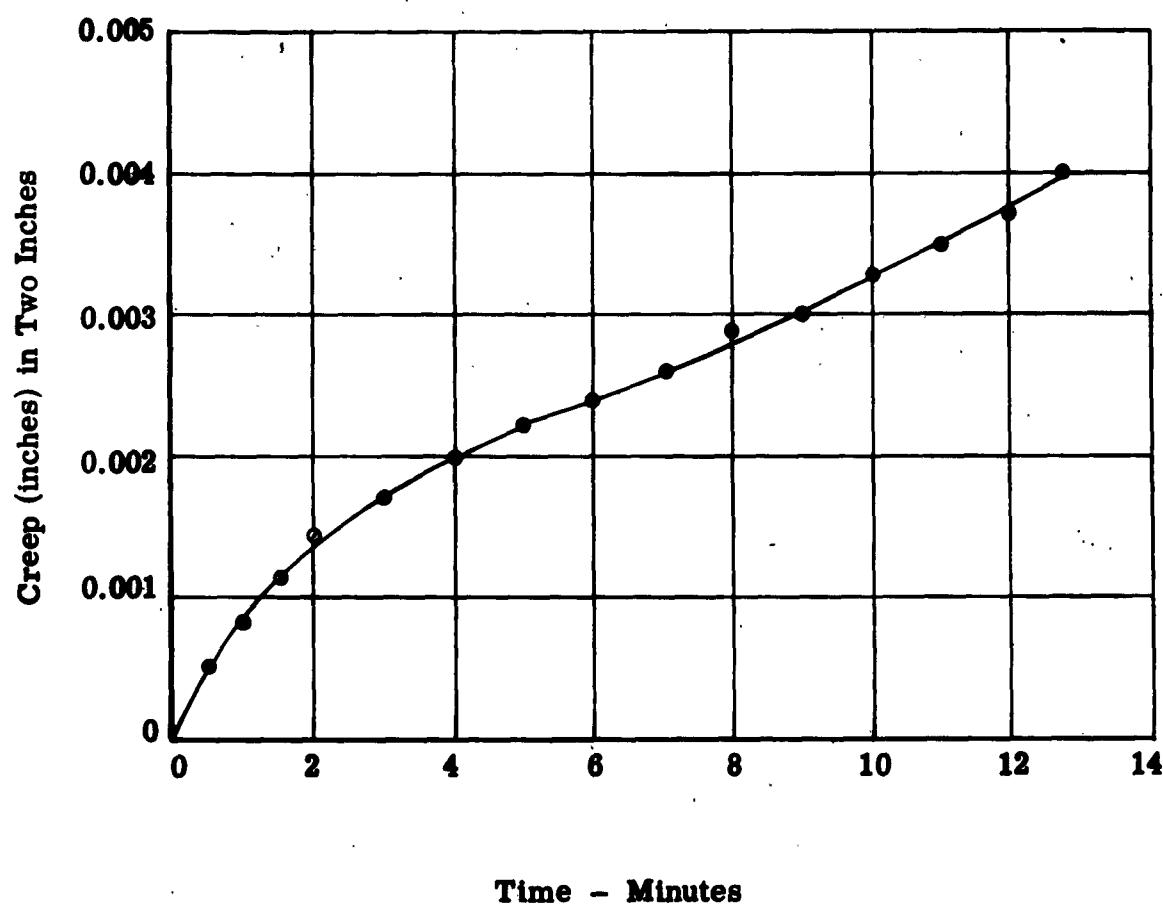


Figure 36. Creep versus Time Curve for Ta-10W Alloy 2800°F

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Ta - 10W
Spec. 5-8
Stress 2900 psi
3100°F

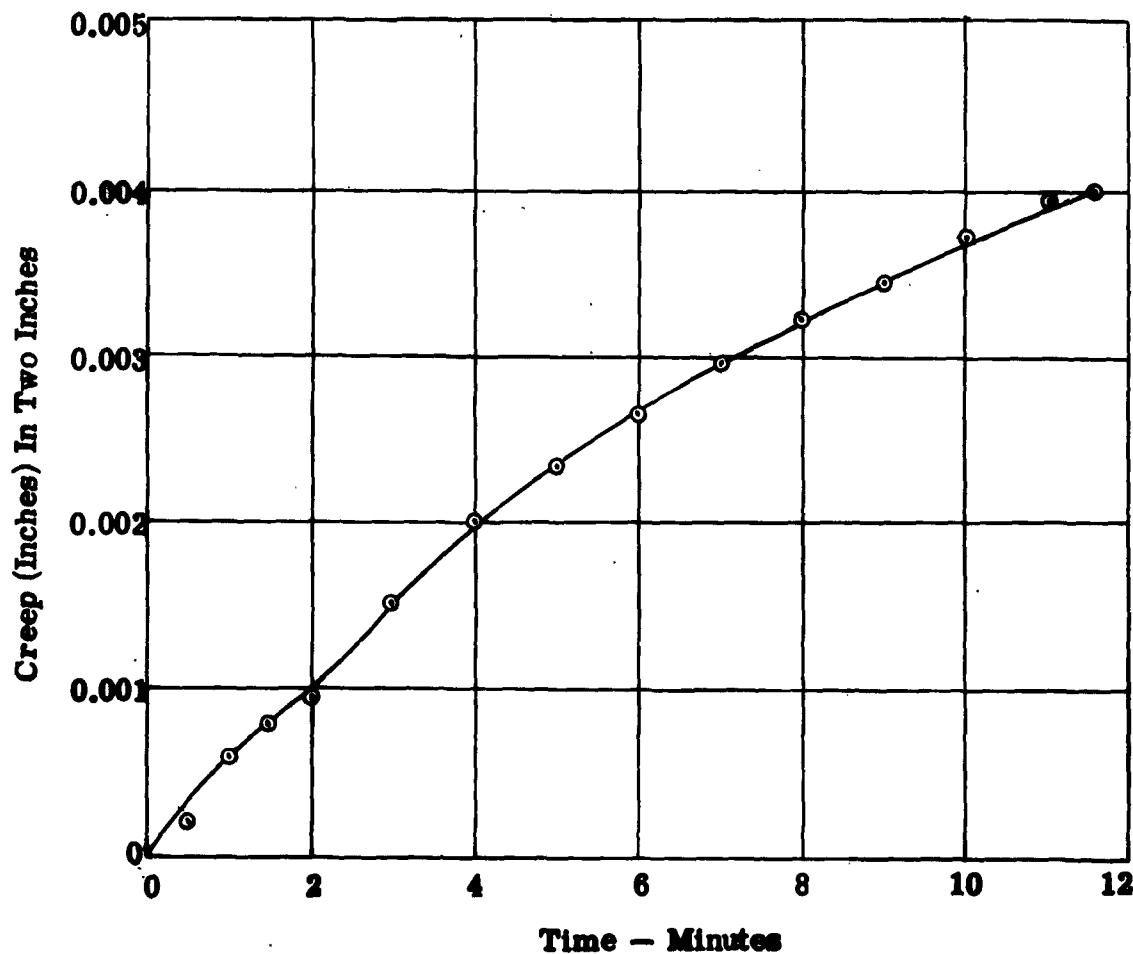


Figure 37. Creep Versus Time Curve for Ta-10W Alloy 3100°F

Ta-10W
Spec 5-5
Stress 2310 psi
3400°F

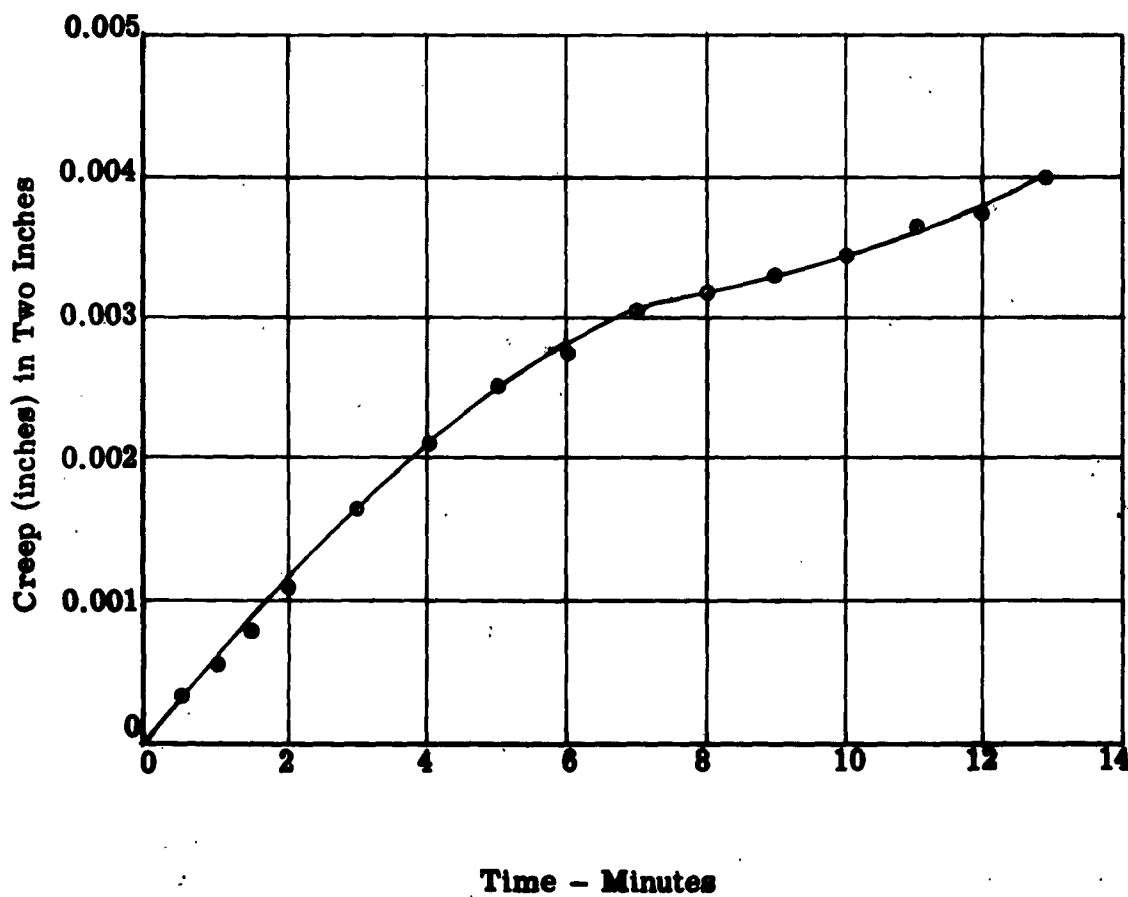


Figure 38. Creep versus Time Curve for Ta-10W Alloy 3400°F

Ta - 10W
Spec 5-2
Stress 3800 psi
3400°F

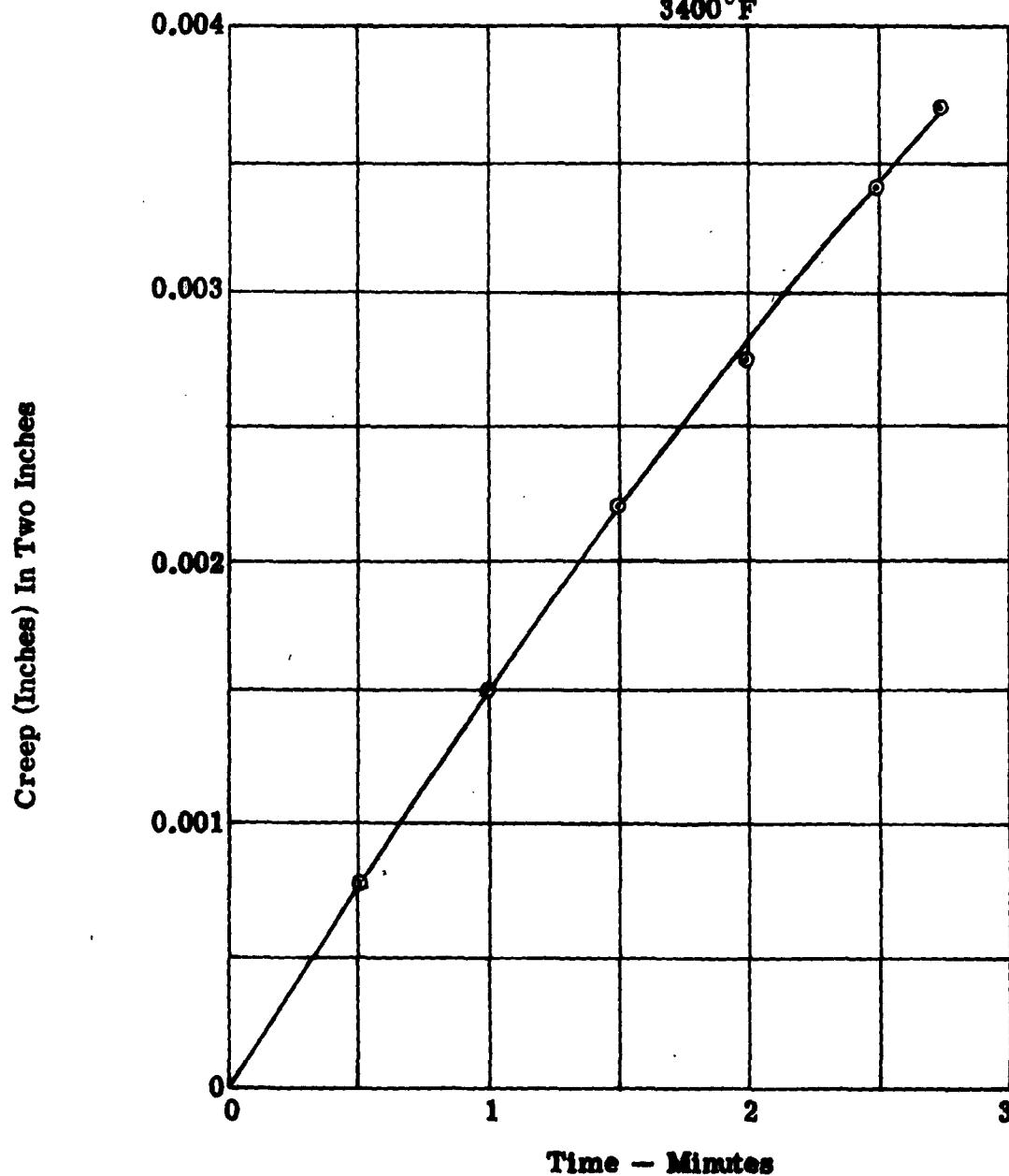


Figure 39. Creep Versus Time Curve for Ta-10W Alloy 3400°F

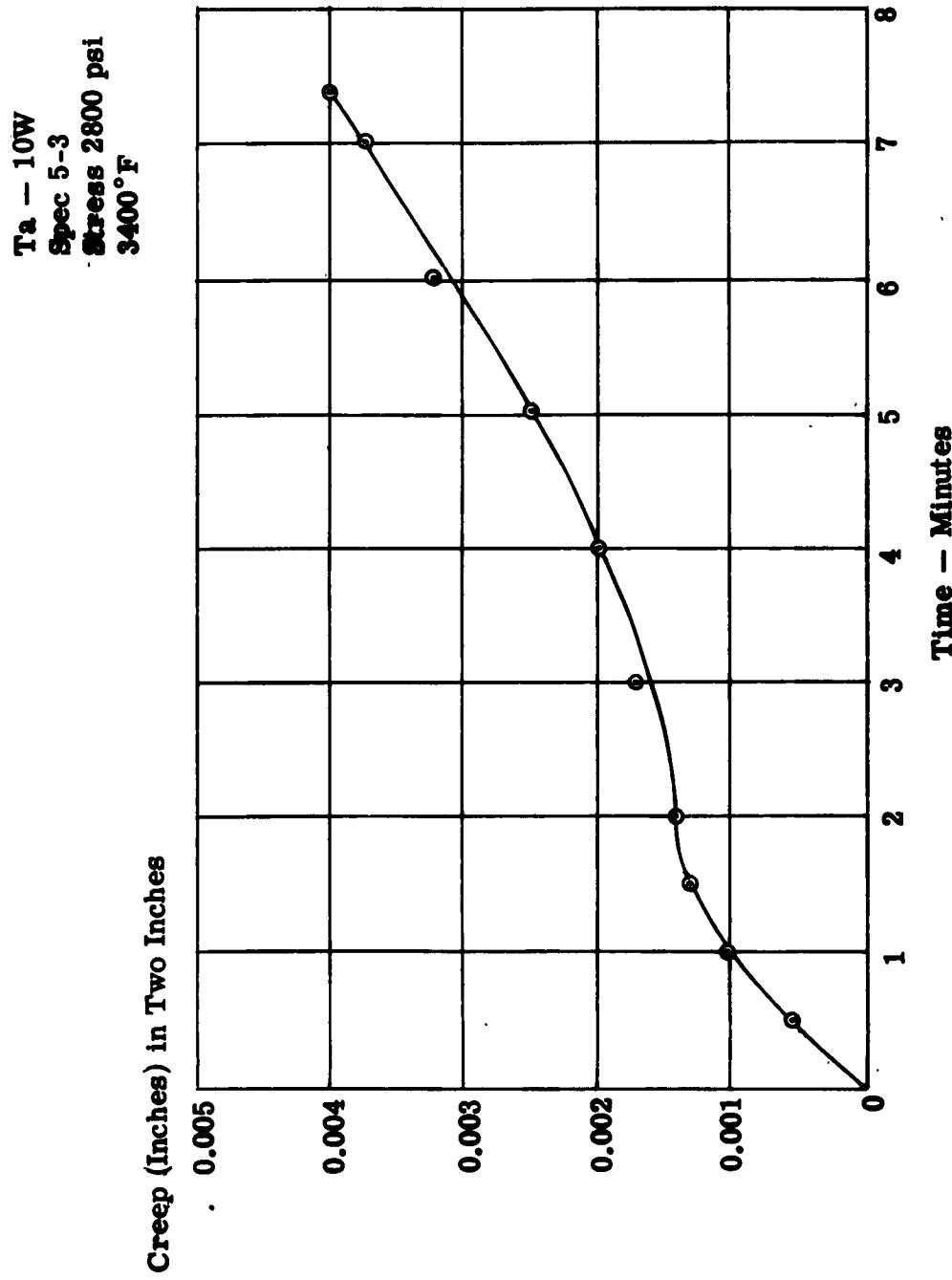
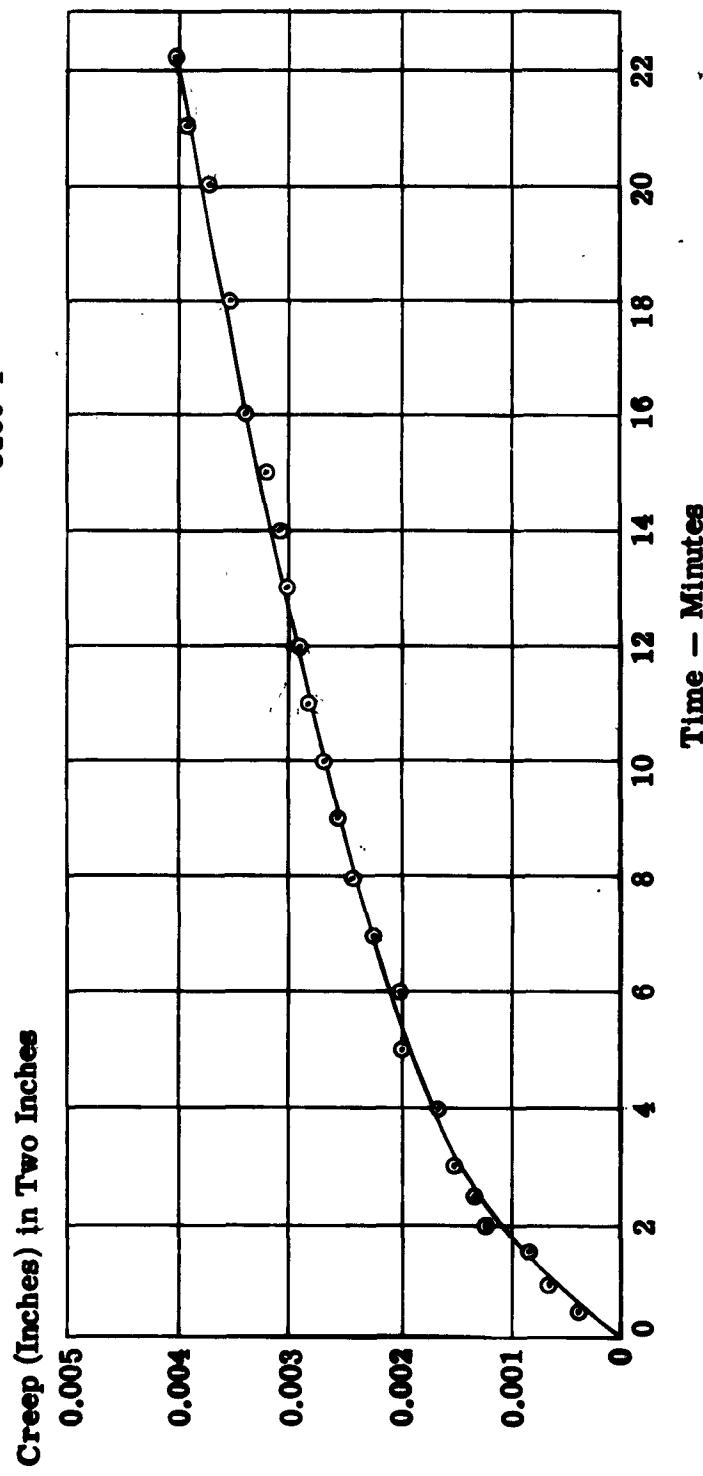


Figure 40. Creep Versus Time Curve for Ta-10W Alloy 3400°F

B - 33
Spec 2-9
Stress 548 psi
3100°F



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Figure 41. Creep Versus Time Curve for B-33 Alloy 3100°F

B-33
Spec 2-10
Stress 852 psi
3100°F

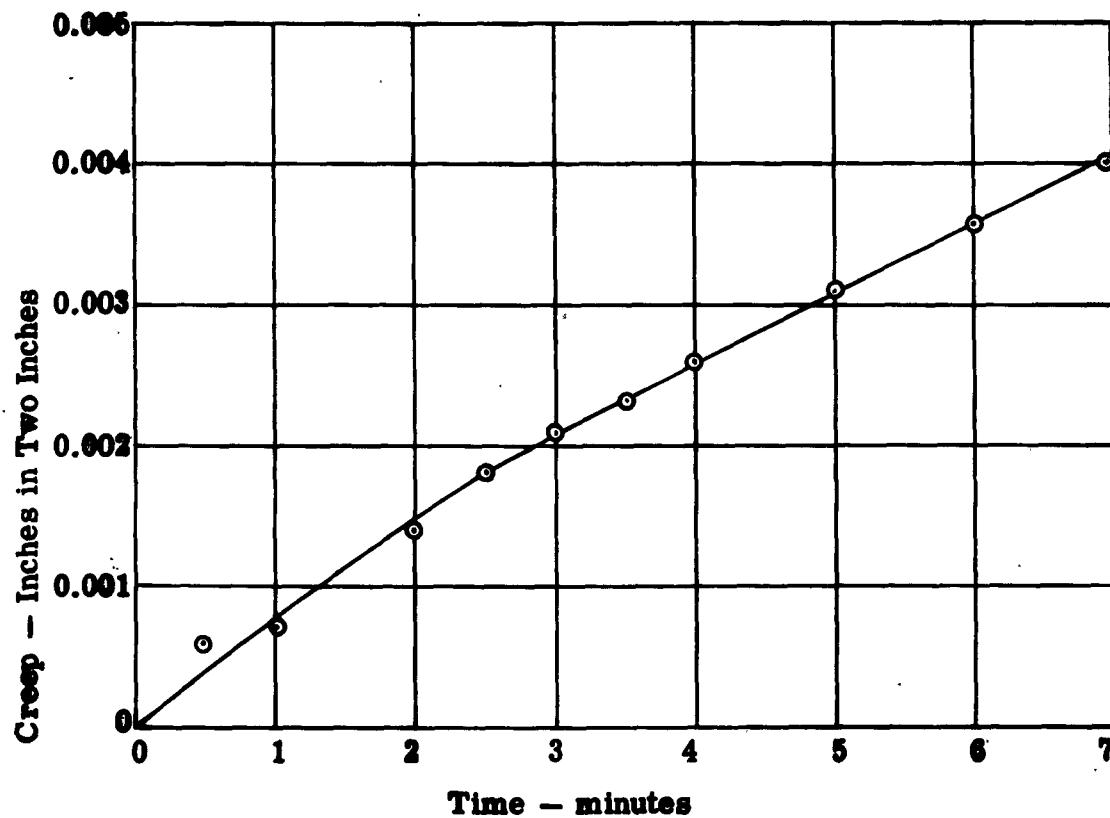


Figure 42. Creep Versus Time Curve for B-33 Alloy 3100°F

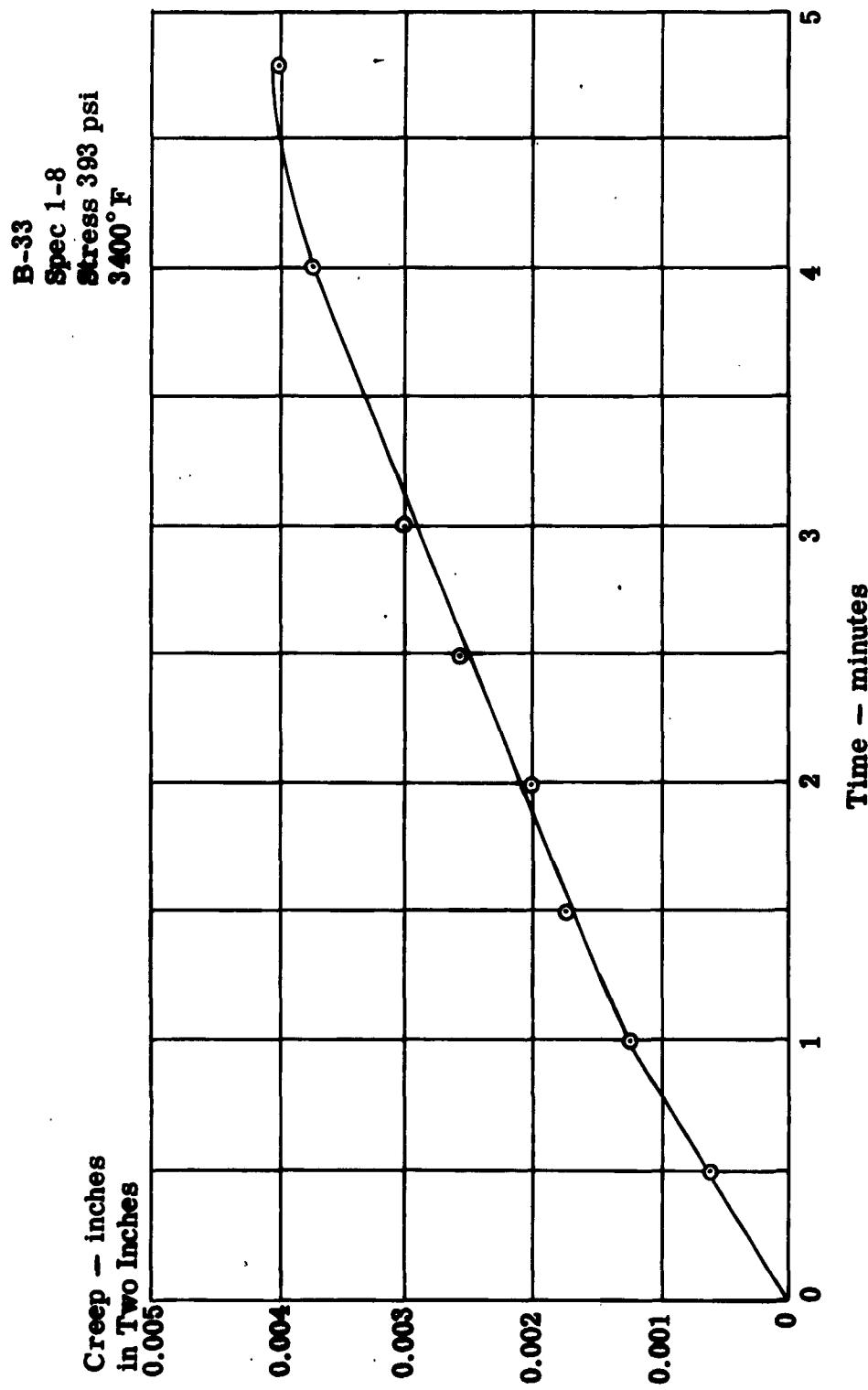
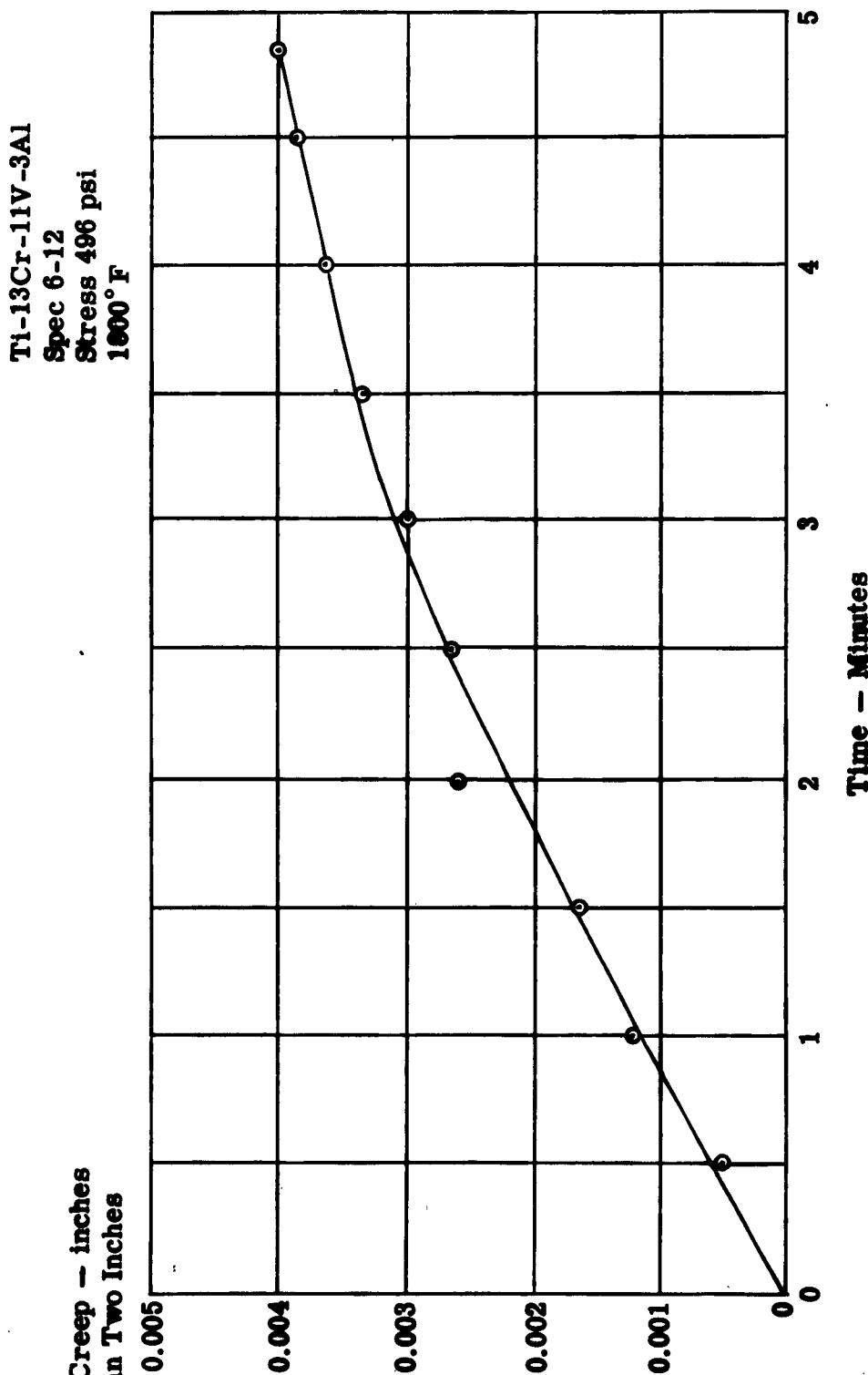


Figure 43. Creep Versus Time Curve for B-33 Alloy 3400°F



BLR 62-26 (M)

Figure 44. Creep Versus Time for Ti-13Cr-11V-3Al Alloy 1800°F

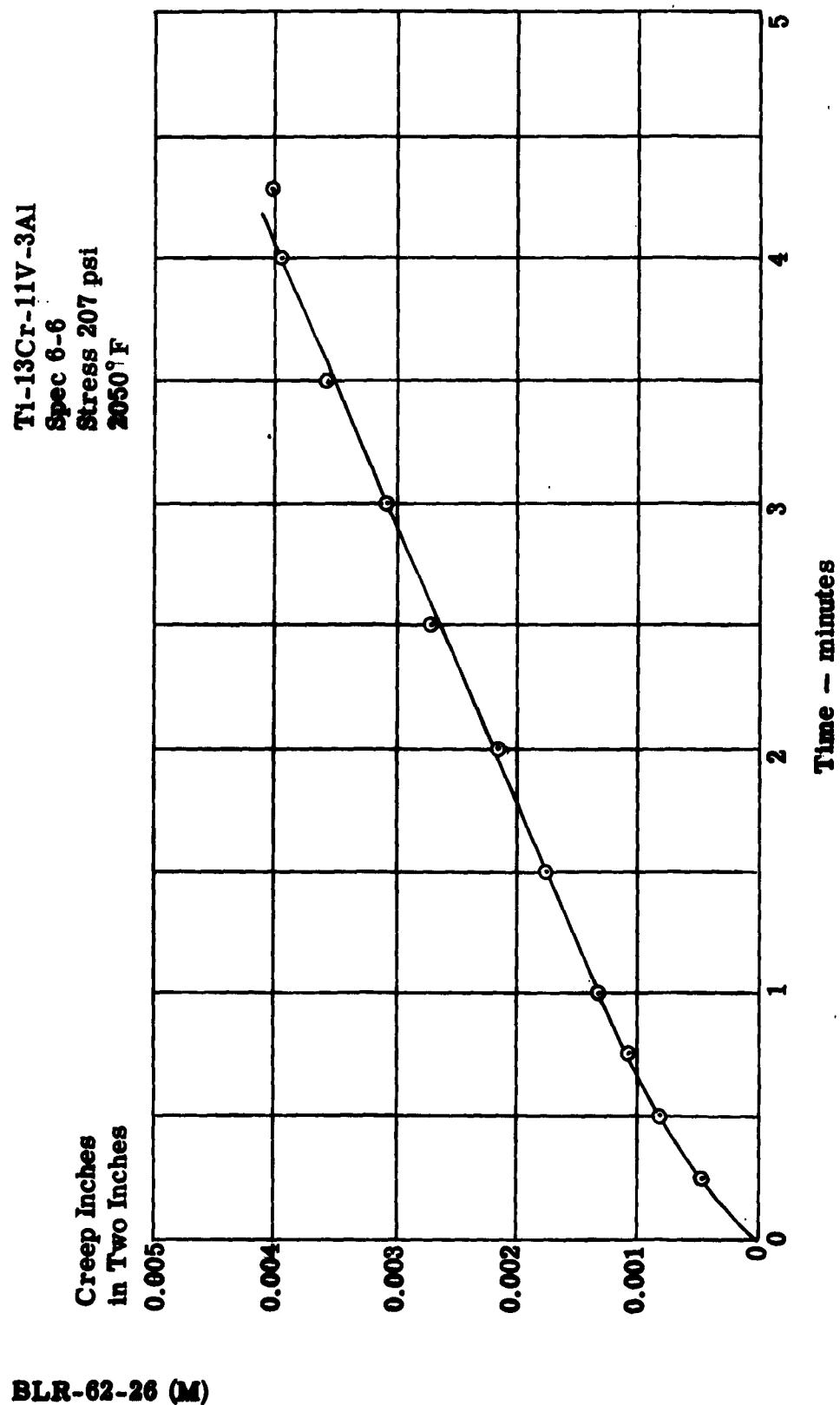


Figure 45. Creep Versus Time for Ti-13Cr-11V-3Al Alloy 2050°F

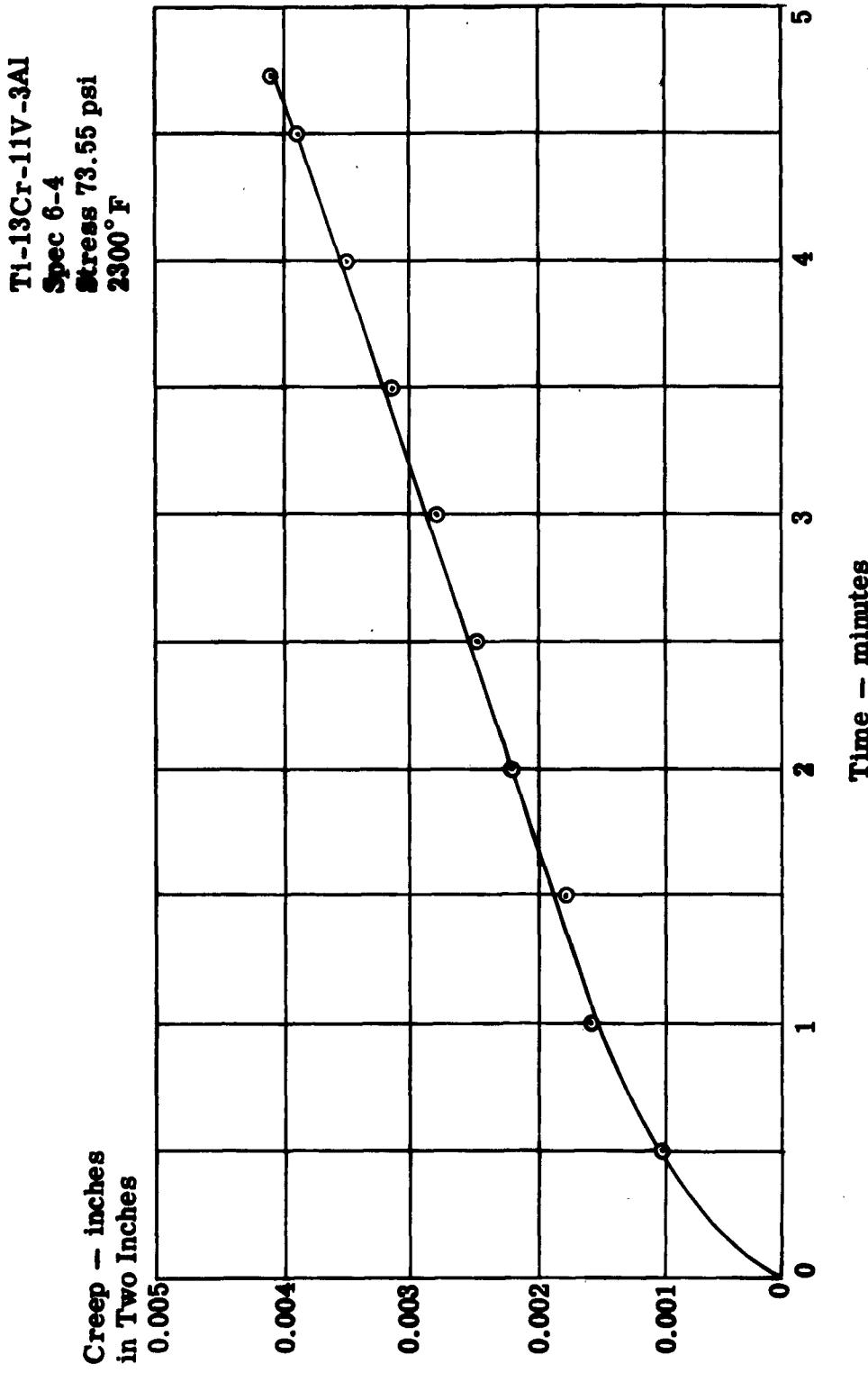


Figure 46. Creep Versus Time for Ti-13Cr-11V-3Al Alloy 2300°F